TRANSACTIONS
OF THE
AMERICAN PHILOSOPHICAL SOCIETY

Plains Cree: A Grammatical Study. H. CHRISTOPH WOLFART.
Vol. 63, pt. 5, 90 pp., 1973. **$4 00**

Arms Across the Border: United States Aid to Juárez During the French Intervention in Mexico. ROBERT RYAL MILLER.
Vol. 63, pt. 6, 68 pp., 1973 **$2.50.**

F. A. Smitt, Marine Bryozoa, and the Introduction of Darwin into Sweden. THOMAS J. M. SCHOPF and EDWARD L. BASSETT.
Vol 63, pt. 7, 30 pp., 1973. **$2.50**

The "Real Expedición Marítima de la Vacuna" in New Spain and Guatemala. MICHAEL M. SMITH.
Vol 64, pt. 1, 74 pp., 1974 **$4.00.**

Bellièvre, Sully, and the Assembly of Notables of 1596. J. RUSSELL MAJOR.
Vol 64, pt. 2, 34 pp., 1974. **$2.00.**

The Sacred Officials of the Eleusinian Mysteries. KEVIN CLINTON.
Vol. 64, pt. 3, 143 pp., 17 figs., 1974. **$12.00.**

Mappae Clavicula: A Little Key to the World of Medieval Techniques. CYRIL STANLEY SMITH and JOHN G. HAWTHORNE.
Vol. 64, pt. 4, 128 pp., 1 fig. (color), 40 pls., 1974. **$7.00.**

Benjamin Rush: Philosopher of the Revolution. DONALD J. D'ELIA.
Vol. 64, pt. 5, 113 pp., 1974. **$5.00.**

Ritual Structure and Language Structure of the Todas. MURRAY B. EMENEAU.
Vol. 64 pt. 6, 103 pp., 1974. **$6.00.**

Gears from the Greeks: The Antikythera Mechanism—A Calendar Computer from ca. 80 B. C. DEREK DE SOLLA PRICE.
Vol. 64, pt. 7, 70 pp. 45 figs., 1974. **$5.00.**

The Imperial Library in Southern Sung China, 1127–1279. JOHN H. WINKELMAN.
Vol. 64, pt. 8, 61 pp., 8 figs., 1974. **$5.00.**

The Czechoslovak Heresy and Schism: The Emergence of a National Czechoslovak Church. LUDVIK NEMEC.
Vol. 65, pt. 1, 78 pp., 1975. **$6.00.**

Distractions of Peace During War: The Lloyd George Government's Reactions to Woodrow Wilson, December 1916–November 1918. STERLING J. KERNEK.
Vol. 65, pt. 2, 117 pp., 1975. **$6.00.**

Classification and Development of North American Indian Cultures. A Statistical Analysis of the Driver-Massey Sample. HAROLD E. DRIVER and JAMES L. COFFIN.
Vol. 65, pt. 3, 120 pp., 12 figs., 5 maps, 1975. **$7.00.**

The Flight of Birds. CRAWFORD H. GREENEWALT.
Vol. 65, pt. 4, 67 pp., 42 figs., 1975. **$6.00.**

PROCEEDINGS

OF THE

American Philosophical Society

Held at Philadelphia for Promoting Useful Knowledge

◆

VOLUME 119, NUMBER 5 OCTOBER 15, 1975

CONTENTS

Big Bang Cosmology and the Cosmic Black-Body Radiation. RALPH A. ALPHER AND ROBERT HERMAN 325

The National Gallery of Art: An American Experiment. PAUL MELLON 349

On Illusion and Allusion in Italian Sixteenth-Century Portrait Busts. IRVING LAVIN 353

Fertility Differentials Between Less Developed and Developed Regions: Components and Implications. SIMON KUZNETS 363

Criticism as Evaluation. RENÉ WELLEK 397

I. Minis Hays, Secretary, Librarian, and Benefactor of the American Philosophical Society. WHITEFIELD J. BELL, JR. 401

◆

THE AMERICAN PHILOSOPHICAL SOCIETY
INDEPENDENCE SQUARE
PHILADELPHIA

1975

PUBLICATIONS

OF

The American Philosophical Society

The publications of the American Philosophical Society consist of PROCEEDINGS, TRANSACTIONS, MEMOIRS, and YEAR BOOK.

THE PROCEEDINGS contains papers which have been read before the Society in addition to other papers which have been accepted for publication by the Committee on Publications. In accordance with the present policy one volume is issued each year, consisting of six bimonthly numbers, and the price is $8.00 net per volume. Current price for individual numbers is $1.50.

THE TRANSACTIONS, the oldest scholarly journal in America, was started in 1769 and is quarto size. In accordance with the present policy each annual volume is a collection of monographs each issued as a part. The current annual subscription price is $20.00 net per volume.

Each volume of the MEMOIRS is published as a book. The titles cover the various fields of learning; most of the recent volumes have been historical. The price of each volume is determined by its size and character.

The YEAR BOOK is of considerable interest to scholars because of the reports on grants for research and to libraries for this reason and because of the section dealing with the acquisitions of the Library. In addition it contains the Charter and Laws, and lists of present and former members, and reports of committees and meetings. The YEAR BOOK is published about April 1 for the preceding calendar year. The current price is $5.00.

An author desiring to submit a manuscript for publication should send it to the Editor, George W. Corner, American Philosophical Society, 104 South Fifth Street, Philadelphia, Pa. 19106.

Copyright © 1975 by The American Philosophical Society
Printed in U. S. A.
US ISSN 003-049X

BIG BANG COSMOLOGY AND THE COSMIC BLACK-BODY RADIATION

RALPH A. ALPHER *

Corporate Research and Development, General Electric Company, Schenectady, New York

and

ROBERT HERMAN *

Research Laboratories, General Motors Corporation, Warren, Michigan

(*Read April 25, 1975*)

> Gie me ae spark o' Nature's fire,
> That's a' the learning I desire.
>
> Robert Burns—*First Epistle to J. Lapraik* (1786)

INTRODUCTION

THERE IS every reason to suppose that for as long as man has been a sentient being he has wondered about the nature of his environment, particularly the astronomical universe. For thousands of years the observer of the cosmos cloaked his ignorance in man-made mythological concepts. We submit, we hope without presumption, that man is now in a position to consider plausible models of the universe which represent the integration of and extension to nature in the large of well-established physical laws which he is able to verify directly on a smaller scale or in the laboratory. Moreover, despite the awesome scale and detailed complexity of the astronomical universe, the principal features can be described with relative simplicity and an astonishingly small number of parameters.

The high mythological content of man's view of the universe persisted into the twentieth century (Munitz, 1957; North, 1965). The turning point from which modern cosmology may be traced was Einstein's general theory of relativity, which provided for the first time a conceptual physical framework for dealing with problems on a cosmic scale (Einstein, 1916, 1955). In particular, Einstein's theory represented gravitation, the force through which all objects in the universe interact, as a geometrical construct which enables one to deal with the physical properties of the universe as a whole. Einstein was himself the first to use his theory to construct a cosmological model of the universe (Einstein, 1917, 1923). He found his model to be unstable with respect to expansion or contraction. At that time, however, static behavior was believed to be a proper representation of the nature of the universe, and Einstein therefore introduced into his theory a quantity which he termed the cosmological constant in order to obtain a time-independent model (Einstein, 1917, 1923).

Some years later Friedman (1922, 1924) and independently Lemaître (1931; see also McCrea, 1970) studied various non-static cosmological models arising from the Einstein theory. It is interesting that Lemaître considered a closed universe containing both matter and radiation. Later Tolman (1931, 1934) described a non-static model containing only radiation. Meanwhile, de Sitter (1930, 1931) obtained analytic solutions of Einstein's equations for the so-called open, flat, and closed (or oscillating) models both with and without the Einstein cosmological constant. All of the non-static cosmological models gained credence when during the 1920's Edwin Hubble (1929, 1936) interpreted the redshifts of extra galactic nebulae which he, Humason, and Slipher had been observing, as indicating that the universe was expanding and therefore non-static. It is interesting to note that Lemaître, building on the dynamic solutions, developed a qualitative picture of the universe as having originated in the explosion of an all-encompassing primeval atom (Lemaître, 1950). While Einstein (1931) subsequently regretted his introduction of the cosmological constant into the model, the con-

---

* The Magellanic Premium of the American Philosophical Society was awarded to Ralph A. Alpher and Robert Herman on April 25, 1975, for their prediction of the black-body radiation from the early "explosion" of the Universe.

PROCEEDINGS OF THE AMERICAN PHILOSOPHICAL SOCIETY, VOL. 119, NO. 5, OCTOBER 1975

stant has nevertheless proved to be useful in some variants of what are now called the standard Friedman-Lemaître solution (Weinberg, 1972). Evidence that there is a true expansion (Field, Arp, and Bahcall, 1973) and that the universe is homogeneous and isotropic in the large has been improved and strengthened over the years (Peebles, 1971; Weinberg, 1972).

The prediction of the relict black-body radiation had its origin in the convergence of the concept of non-static cosmological models with the realization that unusual physical conditions might be required for explaining the observed universal abundance distribution of the chemical elements (Gamow, 1946; Alpher, Bethe, and Gamow, 1948). During the same period when the non-static models were being developed, other investigators were becoming convinced that the observed relative abundances of the elements were indeed representative of the composition of the universe. From 1922 through the mid-1940's various investigators had attempted to understand these cosmic abundances as having resulted in some way from a rapid freezing-in of a state of thermodynamic equilibrium among nuclei (see surveys by Alpher and Herman, 1950, 1953). Such an equilibrium had necessarily to be at a very high temperature and density in order to permit the relative abundances to develop according to the relative stability of nuclei. As it turned out it proved impossible to establish single values of temperature and density which were satisfactory over the entire range of elements, although different sets of values were appropriate for restricted segments of the relative abundance distribution. In what proved to be one of the last major efforts in equilibrium theory, Chandrasekhar and Henrich (1942), developing earlier ideas of von Weizsäcker (1938), concluded that while one could not explain the relative abundances as arising from a single set of conditions at thermodynamic equilibrium, the entire abundance distribution must nevertheless be involved in determining the requisite conditions for nucleosynthesis. It is interesting that the current theories of element synthesis in stellar interiors and surfaces are in fact a properly chosen mix of equilibrium and non-equilibrium considerations (Burbidge, Burbidge, Fowler, and Hoyle, 1957; Clayton, 1968; Fowler, 1967; Fowler and Stephens, 1968; Tayler, 1972).

It was in the context of the failure of the earlier equilibrium theories that it was proposed early by Gamow (1935) that thermonuclear reactions, and in particular neutron-capture reactions, were basic to the synthesis of the chemical elements. By 1946 Gamow (1946) had concluded that it was necessary to seek a non-equilibrium locale for nucleosynthesis and suggested that this locale might be the very early stages of the expanding universe. The implementation of these ideas with a non-equilibrium theory of element formation suggested that the then current concept of a Friedman-Lemaître model—a Big Bang universe—had to be generalized to one consisting of a mixture of matter and radiation rather than matter only. In fact, the ranges of the density of matter and of the temperature required for non-equilibrium synthesis of the elements suggested a cosmological model which at early times consisted almost entirely of radiation with matter present in trace amounts (Alpher, 1948*a*, *b*). Our later studies of the physics of such a model at early times and of its evolution as the universe expanded and cooled led to our theoretical prediction (Alpher and Herman, 1948*a*, 1949) that there should now be a very low temperature residual black-body radiation pervading the universe.

In the remainder of this paper we review briefly the development of current understanding of the physics of the Big Bang model of the universe. In particular, we describe the underlying cosmological models and the role played by non-equilibrium theories of nucleosynthesis, and then remark on the physical character of the early universe and its subsequent evolution. Using this background we describe our own research in 1948 and 1949 leading to the prediction of the existence of the relict black-body radiation and the original estimation of its present temperature (see also Alpher, Gamow, and Herman, 1967). We then review the observational discovery of this cosmic microwave background by Penzias and Wilson (1965) as well as the many other corroborative observations, a few of which had actually been made earlier but not interpreted properly in this particular context (see Thaddeus, 1972). The many observations made over the last decade now appear to confirm that the black-body radiation temperature is approximately 2.7 to 2.8°K. The variation of the intensity of the black-body radiation with wavelength required by the Planck distribution is indeed observed over a rather large range. Moreover the radiation appears to be unpolarized and remarkably isotropic, facts consistent with the simple cosmological model underlying these concepts.

The discussion in this paper is far too brief to permit an exhaustive review or critique of the entire field and the now very large literature that has developed. Any omissions are inadvertent, or represent an attempt to be selective for illustrative purposes.[1]

PHYSICAL PROPERTIES OF THE BIG BANG COSMOLOGICAL MODEL

The model of the expanding universe with which we deal, then, is one containing a homogeneous, isotropic mixture of matter and black-body radiation. Except for the very earliest instants of the expansion, matter and radiation are assumed to be non-interconverting, and the mixture is treated as an ideal fluid. The relativistic energy equation, which describes the time rate of expansion of such a model, is derived from the Einstein field equations, and can be written in the form (Tolman, 1934)

$$\frac{dl}{dt} = +\sqrt{\frac{8\pi G}{3}\rho l^2 - \frac{c^2 l_0^2}{R_0^2}}, \tag{1}$$

in which G is the constant of gravitation; l is any proper distance, i.e., the distance between arbitrarily chosen points in space-time whose change with time we consider; l_0, the unit of length, chosen for convenience to be the side of a cube presently containing one gram of matter; and R_0, the radius of curvature of the universe, determined from the boundary conditions for equation (1). It should be emphasized that the expansion rate depends on the density of mass, i.e., matter plus radiation, and on the radius of curvature. One can show that the pressure of matter and, equivalently, the density of kinetic energy, contribute insignificantly to the dynamics of the expansion. Solutions of equation (1) involve l/l_0 and not l alone, which means that the evolution of the model is described in terms of relative rather than absolute values of the scale factor.[2] The density of all mass,[3] ρ, which together with R_0 determines the geometry of the model, is the sum of the density of matter ρ_m and the density of radiation ρ_r. If matter is to be conserved in any chosen volume of initial radius n, i.e., $v = (4/3)\pi n^3 (l/l_0)^3$, then clearly we require

$$\rho_m (l/l_0)^3 = A = \text{constant}. \tag{2}$$

The radiation in the universe is characterized as obeying the black-body law, so that the density of radiation ρ_r is given by

$$\rho_r = \frac{4\sigma}{c^3} T^4 \text{ gm/cm}^3, \tag{3}$$

where σ is the Stefan-Boltzmann constant, and c is the velocity of light. Since the universal expansion is adiabatic then the temperature, T, must vary as $1/l$ (Tolman, 1931, 1934). Hence

$$\rho_r (l/l_0)^4 = B = \text{constant}. \tag{4}$$

A property of this model is that proper energy is not conserved in any finite volume element we choose to follow in the expansion.

---

[1] There are a number of excellent and reasonably current reviews or treatises that cover in greater detail much material we must necessarily gloss over, and that contain more comprehensive bibliographies. Most recent and most complete is the book of Weinberg (1972); perhaps less comprehensive but very useful reviews are those of Peebles (1971), Sciama (1971), and Harrison (1973). There are older but nevertheless interesting surveys by Zeldovich (1965, 1967), a short review by Partridge (1969), and our own very condensed historical views (Alpher, Gamow, and Herman, 1967; Alpher and Herman, 1972). The treatise by Tolman (1934) has been a standard in cosmology for many years. Other recommended reviews include McCrea (1968, 1970) and, of course, Einstein (1955).

[2] Equation (1) contains a mathematical singularity, i.e., the density becomes infinite as l and t go to zero. However, it is likely that equation (1) is not a correct description of nature for the first fractions of a second after the start of the Big Bang (Alpher, Follin, and Herman, 1953; Harrison, 1973; Weinberg, 1972), a period during which the behavior of the expansion is governed by the properties of elementary particles and radiation under very extreme conditions, and where Einstein's general theory of relativity may not be applicable. This period when $t \ll 1$ second is a fascinating regime in which to apply the growing knowledge of particle and field theory (see Alexanian and Mejía-Lira, 1975; Alpher, Follin, and Herman, 1953; Carlitz, Frautschi, and Nahm, 1973; Carr, 1975; Carr and Hawking, 1974; Harrison, 1973; Novikov and Zeldovich, 1973; Sisteró, 1973; Stauffer, 1972; Stewart, 1969; Sunyaev and Zeldovich, 1970; Szalay and Marx, 1974; Tryon, 1973; Zeldovich, 1970). However, this is certainly beyond the scope of the present paper, where we deal with the model only after matter and radiation are no longer interconverting.

[3] Throughout this discussion we deal with a smeared-out density of matter, i.e., the equivalent density of matter in the universe if all the matter which is observed were uniformly dispersed, or, equivalently, if there had been no condensations into stars or galaxies during the evolution. The present scale of organization of matter is approximately 30 Mpc $\cong 100 \times 10^6$ light years. The density of radiation is simply the mass equivalent of the energy content, E, of the radiation field in the volume, V, in the sense $E/V = \rho_r c^2$ ergs cm^{-3}.

An interesting relation which is basic to the prediction of the relict radiation results from combining equations (2) and (4), namely,

$$\rho_r \rho_m^{-\frac{4}{3}} = \text{constant}. \tag{5}$$

It is clear that this relation must hold throughout the universal expansion and that the density of mass, ρ, at any epoch is given by

$$\rho = \rho_m + \rho_r = A(l/l_0)^{-3} + B(l/l_0)^{-4}, \tag{6}$$

providing, as stated earlier, there is no interconversion between matter and radiation. Substituting equation (6) into equation (1) yields a new form for the relativistic energy equation, namely,

$$\frac{1}{L}\frac{dL}{dt} = +\sqrt{\frac{8\pi G}{3}\left(\frac{\rho_{m''}}{L^3} + \frac{\rho_{r''}}{L^4}\right) - \frac{c^2}{L^2 R_0^2}}\,. \tag{7}$$

where

$$L = \frac{l}{l_0}\,. \tag{8}$$

In equation (7) we have chosen to define the constants Al_0^{-3} and Bl_0^{-4} as values at $L = 1$ (where $L = 1$ defines the present epoch) of the densities of matter, $\rho_{m''}$, and of radiation, $\rho_{r''}$. Equation (7) defines three basically different modes of behavior during expansion, depending upon whether R_0, the radius of curvature of the universe, is real, imaginary, or infinite, i.e., whether the universe is closed, open, or flat, respectively. Equation (7) can be integrated (Friedman, 1924; Lemaître, 1931; de Sitter, 1930, 1931; Alpher and Herman, 1950; Weinberg, 1972) to yield the explicit dependence of the dimensionless proper distance L, and of the densities of matter and radiation, on the epoch t. We shall display these solutions graphically in connection with our later discussion of the temporal behavior of the Big Bang model.

It is useful to note that at very early times, when the expansion is radiation-dominated, one can neglect the matter term $\rho_{m''}L^{-3}$ in equation (7). Moreover, the ratio of the last term, containing the curvature R_0, to the radiation term containing $\rho_{r''}L^{-4}$ varies as L^2 and hence the curvature term is also negligible at small L or early t. Integration of this particular form, using the Stefan-Boltzmann law and the special relation $T \propto 1/l$ for adiabatically expanding black-body radiation, yields

$$T = \left(\frac{3c^2}{32\pi G a}\right)^{\frac{1}{4}} t^{-\frac{1}{2}}\,{}^\circ\text{K} \cong 1.52 \times 10^{10} t^{-\frac{1}{2}}\,{}^\circ\text{K}, \tag{9a}$$

and from equation (3)

$$\rho_r \cong 4.49 \times 10^5 t^{-2}\ \text{gm/cm}^3 \tag{9b}$$

where t is in seconds, and $a = 4\sigma/c$, with σ the Stefan-Boltzmann constant. The functional dependence of temperature or equivalently the radiation density, in equations (9), involves only universal constants and the time and therefore applies at very early times to models be they open, closed, or flat.

In defining $\rho_{m''}$ and $\rho_{r''}$ as above, we have anticipated the boundary condition that for the special choice $L = 1$ equation (7) is in fact a relation giving the value of Hubble's constant, H_0, at the time when $L = 1$, i.e., the presently observed rate of universal expansion:

$$\left(\frac{1}{L}\frac{dL}{dt}\right)_{L=1} = H_0$$

$$= \sqrt{\frac{8\pi G}{3}(\rho_{m''} + \rho_{r''}) - \frac{c^2}{R_0^2}}\,. \tag{10}$$

From equation (10) one finds that if Hubble's constant and the densities of matter and radiation are known at the present time when $L = 1$, then the radius of curvature and therefore the cosmological model is specified. These comments will be seen to be consistent with our opening statement that a reasonable model requires only a few parameters.

In the introduction we suggested that one could on the basis of present knowledge construct plausible models of the universe. The major elements of knowledge leading to this plausibility include not only general relativity, the universal expansion and the black-body radiation, but also two additional considerations. These are counts of radio sources and the cosmic abundances of helium and deuterium.

To the extent that radio sources are distributed uniformly in space, counts of such sources made at successively increasing proper distances and hence at smaller apparent luminosities will give number densities of such objects proportional to the volumes considered. Depending on whether the universal radius of curvature is real, imaginary, or infinite, one should observe a different relation between the number of radio sources per unit solid angle brighter than some

This One
23RB-FL2-D2DF

given intensity, and the intensity. Ryle and his associates (Ryle, 1968; Longair and Rees, 1972; Field, Arp, and Bahcall, 1973) suggest that their extensive studies of extragalactic radio source counts can be explained in terms of the type of non-static model we have been discussing only if there has been evolutionary change of the radio luminosity of these sources as we see them in times past at great distances. However, this interpretation is still considered as being controversial by some investigators (see Burbidge, 1971; Hoyle, 1973) and at the moment must be regarded as weak evidence by itself for an evolving non-static universe.

On somewhat firmer ground is the question of the cosmic abundance of helium and deuterium. In our original studies of nucleosynthesis (Alpher and Herman, 1948*b*, 1949, 1951) we had attempted to understand the cosmic abundance distribution of all the elements as having arisen from rapidly quenched non-equilibrium thermonuclear processes in the early stages of a Big Bang cosmological model. In addition, Gamow (1948) and Fermi and Turkevich (presented by Alpher and Herman, 1950, 1953) had examined in greater detail the abundances of the very lightest elements in the Big Bang model. Since these earlier studies were made, detailed theoretical calculations based on the production of elements by both equilibrium and non-equilibrium processes in stellar interiors and surfaces have proved to be highly successful (Burbidge, Burbidge, Fowler, and Hoyle, 1957; Clayton, 1968; Fowler, 1967; Fowler, 1968; Fowler and Stephens, 1968; Tayler, 1972) with the crucial exception of the abundances of helium and deuterium (Fowler, 1971; Wagoner, 1973). It now appears that, unless highly artificial assumptions are invoked, one must conclude that helium and deuterium were produced in their present cosmic abundances in the early stages of the Big Bang. We shall return to this conclusion later in the discussion.

BLACK-BODY RADIATION

The properties of black-body radiation are certainly not new. They are a classical aspect of physics and have played an important role in the development of the quantum theory of matter and radiation. In order to understand the concept of black-body radiation being relict or residual from the early Big Bang, as well as to understand the observational data we discuss later, it is appropriate to digress here to mention some of the physical characteristics of this type of radiation (Tolman, 1934).

As shown by the classical work of Stefan and Boltzmann, the equivalent mass density of radiant energy in equilibrium with the walls of a hollow enclosure at temperature T is given by equation (3) in which the Stefan-Boltzmann constant σ has the value 5.67×10^{-5} ergs/(cm^2 sec deg^4). The radiation in the enclosure exerts a pressure given by

$$p = \tfrac{1}{3}\rho_r c^2 \text{ dynes/cm}^2. \qquad (11)$$

If the enclosure has a volume V then the total radiant energy in the enclosure is

$$E = \frac{4\sigma}{c} VT^4 \text{ ergs}. \qquad (12)$$

The spectral distribution of the black-body radiation is given by the well-known Planck function, which in frequency units is given by

$$B_\nu d\nu = \frac{2h\nu^3}{c^2}\frac{d\nu}{\exp[h\nu/(kT)] - 1} \text{ ergs/(cm}^2\text{ sec sr Hz)}, \qquad (13)$$

where the quantity B_ν is the monochromatic brightness in the frequency interval $d\nu$ at frequency ν, h the Planck constant,[4] k the Boltzmann constant and c again the velocity of light.

The maximum brightness according to the Planck spectral distribution function in equation (13) occurs at a frequency $\nu_{\max}$, where

$$\frac{Tc}{\nu_{\max}} = 0.3544\frac{hc}{k} = 0.510 \text{ cm deg}. \qquad (14)$$

There are useful and well-known approximations to the Planck function for frequencies higher or lower than the peak (or for wavelengths shorter or longer than the peak, respectively). At long wavelengths the radiation brightness in $d\nu$ at ν is described by the Rayleigh-Jeans law, namely

$$B_\nu d\nu \cong \frac{2kT}{\lambda^2} d\nu \text{ ergs/(cm}^2\text{ sec sr Hz)}, \qquad (15)$$

while at short wavelengths one has the Wien expression

$$B_\nu d\nu \cong \frac{2hc}{\lambda^3} e^{-hc/(kT)} d\nu \text{ ergs/(cm}^2\text{ sec sr Hz)}. \qquad (16)$$

---

[4] It is interesting that Noerdlinger (1973) argues that the existence of the ~2.7°K relict radiation rules out any secular variation as large as 10 per cent in Planck's constant, for most of the age of the universe.

The Rayleigh-Jean region appears as a straight line on a plot of the logarithm of brightness versus the logarithm of the wavelength, as will be seen later in figure 5 where we compare the Planck distribution with observations of the black-body relict radiation. It should be noted that usage in the present context has led to plotting the Planck function, calculated in frequency units according to equation (13), against wavelength.

Whereas equation (14) expresses the relation between black-body temperature and the frequency at maximum brightness, a more useful expression for our purpose relates the temperature and the wavelength at maximum brightness, $\lambda_{\max}$. This is the Wien displacement law, namely,

$$T\lambda_{\max} = 0.290 \text{ cm deg.} \qquad (17)$$

Wien's displacement law provides a simple way of describing the adiabatic expansion of black-body radiation. One can choose to interpret the wavelength λ in this law as an arbitrary length whose scale change with time is given by equation (7). Since the temperature of the adiabatically expanding black-body radiation scales as (Tolman, 1934)

$$T \propto \frac{1}{l}, \qquad (18)$$

a relation which we have already used earlier, then clearly we can write l/λ = constant. This defines immediately what is meant by describing the relict black-body radiation as redshifted primeval black-body radiation, or fossil radiation, from the earliest stages of the Big Bang. It follows that the redshift defined as $z = d\lambda/\lambda$ is given through the relation

$$\begin{aligned} 1 + z &= \frac{\lambda + d\lambda}{\lambda} \\ &= \frac{L_0 \text{ (now)}}{L_1 \text{ (at time of emission)}}\,. \end{aligned} \qquad (19)$$

Consider a spectral line characteristic of an atomic transmission, which, say, was emitted from a distant luminous source at some past time t when the universal scale factor was L_1. We, the observers, are located at t_{now} with the scale factor of the expansion $L_0 = 1$, and we see the spectral line whose laboratory wavelength is λ shifted by an amount $d\lambda$ as it arrives from a distant source. If we substitute for the spectral line λ the position of the wavelength of the black-body radiation peak, or any other particular wavelength in the black-body distribution, then we can interpret the presently observed distribution as the redshifted black-body distribution from the earliest time of the expansion.

A final and intriguing aspect of black-body radiation in the universe has to do with the dimensionless entropy per baryon, a quantity which we describe below. One can show that this quantity is conserved during the expansion (Alpher and Gamow, 1968; Zeldovich, 1965, 1967) and its numerical value may provide insight into the phenomena occurring during the first fractions of a second of the expansion when the value was determined. The dimensionless entropy per baryon is calculated in the following manner. One starts with the heat capacity of black-body radiation which is given by

$$C_r = \frac{16\sigma}{c}\, T^3 \text{ ergs/(cm}^3\,{}^\circ\text{K)}, \qquad (20)$$

while the heat capacity of the matter present, considered as an ideal gas, is given by

$$C_m = \tfrac{3}{2} nk \text{ ergs/(cm}^3\,{}^\circ\text{K)}, \qquad (21)$$

where n is the concentration of baryons. We then form the dimensionless ratio

$$\frac{C_r}{C_m} = 2\left(\frac{16\sigma T^3}{3ckn}\right), \qquad (22)$$

and note two things. First, this ratio is independent of the time during the expansion since T^3 and n both vary as L^{-3}, while σ, c and k are universal constants. Second, the quantity $16\sigma T^3/(3ck)$, in units cm^{-3}, is the density of dimensionless entropy of the black-body radiation, i.e., the entropy of radiation, $16\sigma T^3/(3c)$, divided by the Boltzmann constant k. Hence

$$\frac{C_r}{C_m} = 2\left(\frac{S}{n}\right), \qquad (23)$$

is twice the dimensionless entropy per baryon, or put differently, simply twice the dimensionless entropy in the radiation field per atom in the universe.

One can, in fact, express equation (22) as a combination of universal constants and the densities of matter and radiation as related by equation (5), with the result (Alpher and

Gamow, 1958)

$$\frac{S}{n} \cong 2.47 \times 10^4 \rho_{r''}{}^{\frac{3}{4}} \rho_{m''}{}^{-1} = \text{constant}, \qquad (24)$$

where $\rho_{m''}$ and $\rho_{r''}$ are the densities of matter and of radiation at a particular elapsed time since the Big Bang. Again, because of equation (5), the product $\rho_{r''}{}^{\frac{3}{4}}\rho_{m''}{}^{-1}$ is independent of the epoch. Anticipating our later discussion, if one takes present values for $\rho_{r''} \cong 4.47 \times 10^{-34}$ gm/cm^3 and $\rho_{m''} \cong 3.41 \times 10^{-31}$ gm/cm^3 as current plausible values, then for the cosmological model which is defined by these densities one has

$$\frac{S}{n} \cong 7.0 \times 10^9 = \text{constant}. \qquad (25)$$

It is interesting that one can show the quantity S/n to be equal, to within numerical factors of order unity, to the ratio of the concentration of photons to baryons,[5] or to the ratio of the pressure of radiation to the pressure of matter.

The full ramifications of equations (23), (24), and (25) are not yet clear. For example, a value of $\sim 10^9$ for the ratio C_r/C_m at least implies a "hot" universe (Alpher and Gamow, 1968; Zeldovich, 1967) in which the temperature of matter tracks the falling temperature of radiation quite exactly during the expansion while there is interaction. When matter and radiation decoupled, as was probably the case after the time of crossover when the matter previously in the form of a plasma recombined, the radiation continued its adiabatic expansion and cooling, maintaining its black-body character. Meanwhile the temperature of matter began to show the effects of other processes, such as the involvement of matter in the formation of galaxies and stars.

Alternatively one can use the value of S/n as a parameter defining a given cosmological model, since it depends on a choice of ρ_m and ρ_r at an arbitrarily chosen epoch, quantities unique to a given model. Thus, one can cast the problem of calculating the Big Bang synthesis of the light elements in terms of S/n as the model-defining parameter (Wagoner, Fowler, and Hoyle, 1967). Yet another application would be to interpret S/n as a measure of the irreversible processes in the very early stages of the universe (Zeldovich, 1967, 1972), and it is intriguing to speculate how the universe emerged from this extremely early period with just the value, no more no less, of S/n which pertains thereafter (Zeldovich, 1967; Weinberg, 1972; Carlitz, Frautschi and Nahm, 1973; Alexanian, 1975; Alexanian and Mejía-Lira, 1975).

Let us now turn to how in fact we originally estimated the present value of the back-body radiation temperature (Alpher and Herman, 1948*a*, 1949, 1950). A moment's consideration of equation (5) suggests that we can write it as

$$\rho_{r'}\rho_{m'}{}^{-\frac{4}{3}} = \rho_{r''}\rho_{m''}{}^{-\frac{4}{3}} = \text{constant} \qquad (26)$$

where the primes and double primes refer to the densities at any two epochs. In our early work on the synthesis of the chemical elements in the initial stages of the expansion, we were able to estimate approximately the necessary conditions for nucleosynthesis, namely the temperature and matter density at a specific early time. In view of the constraint of equation (26) we realized at that time that (Alpher and Herman, 1949) "a knowledge of $\rho_{m'}$ and $\rho_{r'}$ during the element-forming period together with $\rho_{m''}$ (the present matter density) fixes a value for $\rho_{r''}$, the present radiation density." The present radiation density, of course, defines the temperature of the relict black-body radiation through equation (3). As we shall see later one measure of the plausibility of the cosmological model which these quantities define is the actual value of the age one calculates as corresponding to the "present," i.e., when $L = 1$.

In these original calculations we employed the then current best estimate of the mean density of matter in the universe, namely, $\rho_{m''} \cong 10^{-30}$ gm/cm^3 (Alpher and Herman, 1948*a*, 1949). In attempting to understand the formation of the elements in a simple successive-neutron-capture theory we had found that the Big Bang cosmological model combined with the nuclear physics involved required $\rho_{m'} \cong 1.7 \times 10^{-2}$ gm/cm^3 at one second elapsed time, when the temperature was $\sim 1.52 \times 10^{10}$ °K or $\rho_{r'} \cong 4.49 \times 10^5$ gm/cm^3 [see equation (9)]. These values of $\rho_{m''}$, $\rho_{m'}$ and $\rho_{r'}$, were combined in equation (26) to predict a present background radiation density of $\rho_{r''} \cong 10^{-32}$ gm/cm^3, or a present radiation temperature of ~5°K. In a later recalculation of the neutron-capture theory (Alpher and Herman, 1951), we concluded that $\rho_{m'}$ at one second elapsed time might be as low as $\sim 2 \times 10^{-3}$ gm/cm^3 (after correcting for the change in observed neutron half-life since the original calculations). These two values, $\sim 1.7 \times 10^{-2}$ and $\sim 2 \times 10^{-3}$ gm/cm^3, were as close as they are to Wagoner's current value based on detailed calculations for the light elements, namely $\sim 6.9 \times 10^{-2}$ gm/cm^3, because the neutron-capture model, crude as it may have been, was heavily influenced by the need to fit the very lightest element abundances which make up the bulk of cosmic matter.

---

[5] The concentration of photons is obtained by dividing the Planck distribution function, equation (12), by the photon energy $h\nu$ and integrating over all frequencies. The result is $n_{ph} = 16\pi\xi(3)[kT/(hc)]^3 \cong 20.3T^3$ cm^{-3} $\cong 450$ cm^{-3} at 2.8°K. Here $\xi(3)$ is the Riemann zeta function for argument 3.

A good deal of thought has been given to the cosmological significance of the light element abundances. Thus Gamow (1948*b*) tried to deduce $\rho_{m'}$ from studying deuterium synthesis only (see Alpher and Herman, 1948*a*); Peebles (1966) considered He^4 and D in getting at $\rho_{m'}$ shortly after the black-body radiation was observed. Audouze and Tinsley (1974) have recently examined the elements through Li^7 to sort out the locales of origin. Reeves (1972) calculated the residual baryons and neutrinos from early nucleosynthesis in connection with baryon-symmetric cosmologies. Tomita (1972, 1973) and Gisler, Harrison, and Rees (1974) examined the effects of any primordial irregularities on light-element nucleosynthesis. Fowler (1971) emphasized that the prediction of the relict radiation temperature and the helium abundance requires, explicitly or implicitly, that one specify the number densities of electron- and muon-leptons, as well as the baryon density, $\rho_{m'}$, as initial conditions for nucleosynthesis.

The data which led to the approximate value of 5°K as described above have been improved considerably over the years,[6] and we should like now to present what we believe to be a plausible set of values for the pertinent cosmological parameters. Gott, Gunn, Schramm, and Tinsley (1974; Tinsley, 1975) recently examined all of the evidence relevant to a best value of Hubble's expansion rate H_0 and of the present density $\rho_{m''}$. They concluded that a value of $\rho_{m''}$ most consistent with all the evidence is ~0.06 times the mass density required for closure of the universe.[7] The closure or critical density for the universe is obtained by taking $R_0 = \infty$ in equation (10), with the result

$$\rho_{cr} = \frac{3H_0^2}{8\pi G} \cong 1.79 \times 10^6 H_0^2 \text{ gm/cm}^3, \quad (27)$$

where H_0 is in units of sec^{-1}. If we take Sandage's most recent value (Sandage, 1972; Sandage and Tammann, 1975*a,b*) for $H_0 \cong 55$ km/(sec Mpc) $\cong 1.78 \times 10^{-18}$ sec^{-1} [rather than the value 60 km/(sec Mpc) proposed by Gott, Gunn, Schramm and Tinsley (1974)], then $\rho_{cr} \cong 5.68 \times 10^{-30}$ gm/cm^3, and $\rho_{m''} \cong 3.41 \times 10^{-31}$ gm/cm^3.

We now perform the calculation of the temperature of the cosmic black-body radiation in a slightly different manner. Matter conservation since the period of matter-radiation interconversion requires that $\rho_m = \rho_{m''}L^{-3}$, and, since T varies as l^{-1} throughout the expansion, then following Wagoner (1973) we can write $\rho_m = hT_9{}^{-3}$, where T_9 is the temperature in 10^9 °K units, and h is a model-dependent parameter. Furthermore the value of T for any model at early time is described by equation (9). One then chooses from Wagoner's (1973) recent recalculation of light-element abundances that value of h which corresponds to what is now presumed to be the most nearly correct cosmic abundance of deuterium formed in the Big Bang, namely a mass fraction $X(D) \cong 4 \times 10^{-5}$. One finds then $\rho_{m'} \cong 6.87 \times 10^{-2}$ gm/cm^3 at $t = 1$ second, when $T \cong 1.52 \times 10^{10}$ °K according to equation (9), or $\rho_{r'} \cong 4.49 \times 10^5$ gm/cm^3

---

[6] In 1964 Smirnov (1964) re-examined the production of light elements in the Big Bang. While his results have been superseded by the work of Wagoner, Fowler, and Hoyle (1967) and Wagoner (1973), one can infer from the range of matter densities he proposed for nucleosynthesis that he might have estimated the present black-body radiation temperature in the range ~1°K to ~9°K.

[7] One should not read into this statement the notion that the smeared-out mean density of matter in the universe is a settled question. For example, Ostriker, Peebles, and Yahil (1974) suggest that the amount of luminous matter in galaxies may have been underestimated by as much as a factor ten. Moreover, the possibilities of making up "missing" mass by hypothesizing black holes is most intriguing (see, for example, Carr and Hawking, 1974; Chapline, 1975; Napier and Guthrie, 1975). For comments on the matter density and an "open"model with less than the critical density, see Tinsley (1975); Gamow (1968); McCrea (1970); Sunyaev and Zeldovich, 1969. Finally, to emphasize the fluidity of the situation, we call attention to recent work of Gunn and Tinsley (1975) who propose that a plausible model may be one with a positive cosmological constant, real radius of curvature and yet expanding forever, and too dense for early nucleosynthesis.

This One
23RB-FL2-D2DF

from the Stefan-Boltzmann law, equation (3). Finally, using equation (26) to connect the early and present epochs, one calculates $\rho_{r''} \cong 3.81 \times 10^{-34}$ gm/cm³. Again using equation (3) and solving for the corresponding T yields 2.60°K, which is in excellent agreement with the observational estimate. As will be seen later we find in the discussion of the plausible cosmological model a value of $\rho_{m'} \cong 6.0 \times 10^{-2}$ gm/cm³, at one second, which is very close to the value derived form Wagoner's work.

The value of $\rho_{m'}$ required for consistency not only yields the correct deuterium abundance but also gives the mass fraction of He⁴ produced in the Big Bang to be ~24%, which is within the range of the generally accepted correct values. Incidentally, the calculated deuterium production is much more sensitive to the initial conditions chosen for nucleosynthesis than is the helium abundance. Gott, Gunn, Schramm, and Tinsley (1974) comment that correct deuterium production requires that $\rho_{m''}$ and H_0 lie in the ranges $0.05\ \rho_{cr} \leq \rho_{m''} \leq 0.09\ \rho_{cr}$ and 49 km/(sec Mpc) $\leq H_0 \leq$ 65 km/(sec Mpc), respectively. Wagoner (1973) suggests that values of $\rho_{m''}$ for the standard Big Bang model in the range $0.014\ \rho_{cr} \leq \rho_{m''} \leq 0.053\ \rho_{cr}$ are consistent with not only D and He⁴ abundances, but also with the early synthesis of He³.

TEMPORAL BEHAVIOR OF THE BIG BANG MODEL

In contrast to earlier studies in cosmology when one did not know the present value of the relict black-body radiation temperature, it is now possible to add the value of ~2.7°K to the list of observed parameters available to construct various cosmological models. What now appears to be the most plausible set of parameters is the following:

$$H_0 \cong 55 \text{ km/(sec Mpc)} \cong 1.78 \times 10^{-18} \text{ sec}^{-1}$$

$$\rho_{r''} \cong 4.47 \times 10^{-34} \text{ gm/cm}^3, \text{ i.e., } T_{BB} \cong 2.7°\text{K}$$

$$\rho_{m''} \cong 0.06\ \rho_{cr} \cong 3.41 \times 10^{-31} \text{ gm/cm}^3$$

The relativistic energy equation, equation (7), for a simple Big Bang model, can be solved to yield three basically different types of behavior depending on the value of the radius of curvature R_0. With the parameters tabulated above an imaginary value for R_0 is obtained, i.e., the universe is open or hyperbolic. We show in figure 1 the temporal behavior of ρ_m, ρ_r, T, L and the redshift [see equation (19)] in this open model. Here as in figures 2 and 3, the specification of three parameters, namely $\rho_{m''}$, $\rho_{r''}$ and H_0 define the model. In this case the radius of curvature $R_0 \cong 18 \times 10^9\ i$ light years. It should also be noted that $L = 1$, which defines the time when the radiation temperature is ~2.7°K, corresponds to an age of $\sim 16.6 \times 10^9$ years, an age which is satisfactorily long compared to the age of the universe estimated by other methods such as the age of the elements and the age of stars (Gott, Gunn, Schramm, and Tinsley, 1974). The Hubble age, H_0^{-1}, which represents the upper limit to the age of the universe, is $\sim 17.8 \times 10^9$ years. The time at

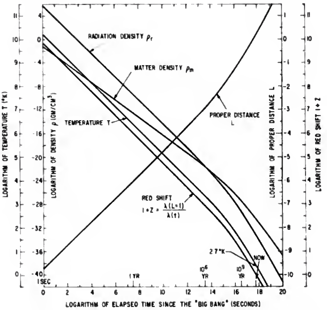

FIG. 1. The plausible "open" cosmological model (imaginary radius of curvature $R_0 = 18 \times 10^9 i$ light years): variation of temperature, densities of matter and radiation, proper distance and redshift with the elapsed time since the Big Bang. Parameters: Hubble's constant $\cong$ 55 km/(sec Mpc); present matter density (= 0.06 times the critical density for closure) $\cong 3.41 \times 10^{-31}$ gm/cm³; relict radiation temperature $\cong$ 2.7°K. Derived quantities: present age $\cong 16.6 \times 10^9$ years; crossover time ($\rho_r = \rho_m$) $\cong 1.3 \times 10^6$ years; crossover temperature $\cong$ 2,000°K; crossover redshift $\cong$ 760; matter density at one second elapsed time $\cong 6.0 \times 10^{-2}$ gm/cm³; radiation density at one second elapsed time $\cong 4.49 \times 10^5$ gm/cm³ (this quantity has the same value for all Friedman-Lemaître models since it involves only the time and universal constants [see equation (9)]. The redshift is plotted according to equation (19). It may be of some interest that the time rate of change of the black-body temperature at long times (like now) is given by $dT/dt \cong -H_0T/L$; with $T_{\text{now}} \cong 2.7°\text{K}$, $L_{\text{now}} = 1$, and $H_0 = 1.78 \times 10^{-18}$ sec⁻¹, then $(dT/dt)_{\text{now}} \cong -4.8 \times 10^{-18}$ °K/sec $\cong -1.5 \times 10^{-4}$ °K/10⁶ years.

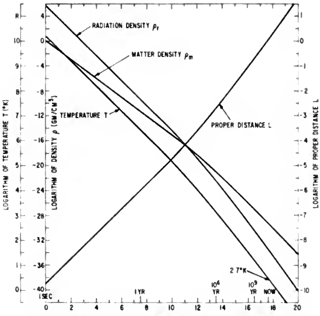

FIG. 2. The "flat" cosmological model (infinite radius of curvature $R_0 = \infty$): variation of temperature, densities of matter and radiation and proper distance with elapsed time since the Big Bang. Parameters: Hubble's constant $\cong$ 55 km/(sec Mpc); present matter density (= critical density for closure) $\cong 5.68 \times 10^{-30}$ gm/cm³; relict radiation temperature $\cong$ 2.7°K. Derived quantities: present age $\cong 11.8 \times 10^9$ years; crossover time ($\rho_r = \rho_m$) $\cong$ 4,800 years; crossover temperature $\cong$ 34,000°K; crossover redshift $\cong$ 12,700; matter density at one second elapsed time $\cong$ 0.63 gm/cm³; radiation density at one second elapsed time $\cong 4.49 \times 10^5$ gm/cm³.

which the matter and radiation densities are equal during the expansion of this model occurs at $\sim 1.3 \times 10^5$ years with a temperature of $\sim$2,000°K and a redshift of $\sim$760. This crossover temperature is consistent with the view that recombination of the primeval plasma occurred during this crossover period (Alpher, Gamow, and Herman, 1967; Peebles, 1968) and the period is undoubtedly significant with respect to anisotropy of the black-body radiation and the conditions for the formation of galaxies (Gamow, 1949, 1953, 1956, 1967; Peebles, 1965).

Although they seem less plausible at the moment, it may be of interest to consider models using the above set of parameters, but with the exception that we take a value for the present density of matter other than the present best value. For example in figure 2 we illustrate the temporal behavior of a model in which the present matter density is taken to be just that required for closure, i.e., a flat universe in which $R_0 = \infty$. Note that the time at which the black-body radiation temperature has reached $\sim$2.7°K, corresponding to the present epoch if the model were reasonable, is $\sim 11.8 \times 10^9$ years. This value of the present age is unacceptably small. Moreover, the crossover time is $\sim$4,800 years and the corresponding temperature is $\sim$34,000°K, which is too high to relate matter-radiation decoupling with crossover.

Finally, we show in figure 3 a third model with the above set of values except that the present matter density is taken as 1.5 ρ_{cr}. This choice of $\rho_{m''}$ generates a closed model of the universe with a real $R_0 \cong 25 \times 10^9$ light years. We note that the time at which the radiation temperature has reached $\sim$2.7°K is as in the previous model also too small, namely $\sim$10.9

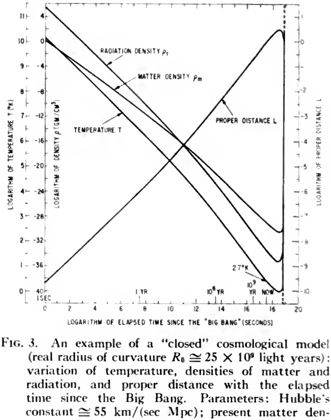

FIG. 3. An example of a "closed" cosmological model (real radius of curvature $R_0 \cong 25 \times 10^9$ light years): variation of temperature, densities of matter and radiation, and proper distance with the elapsed time since the Big Bang. Parameters: Hubble's constant $\cong$ 55 km/(sec Mpc); present matter density (= 1.5 times the critical density for closure) $\cong 8.53 \times 10^{-30}$ gm/cm³; relict radiation temperature $\cong$ 2.7°K. Derived quantities: present age $\cong 10.9 \times 10^9$ years; crossover time ($\rho_r = \rho_m$) $\cong$ 2,140 years; crossover temperature $\cong$ 51,400°K; crossover redshift $\cong$ 19,100; matter density at one second elapsed time $\cong$ 1.5 gm/cm³; radiation density at one second elapsed time $\cong 4.49 \times 10^5$ gm/cm³. In this particular closed model the expansion reverses at $\sim 119 \times 10^9$ years, and returns to a singularity at $\sim 238 \times 10^9$ years. Note that since $T \propto l^{-1}$, and L would reach a maximum of 3 at reversal, the black-body temperature would go to a minimum of 2.8°K/3 $\cong$ 0.9°K.

$\times 10^9$ years, while the time and temperature at crossover are $\sim$2,100 years and $\sim$51,000°K, respectively, the latter again too high.

Since the logarithmic plot of the temporal behavior in figures 1, 2, and 3 tends to obscure the long-time behavior of the models, we display in figure 4 the behavior of the proper distance in each of these three models as a function of time elapsed since the Big Bang on a linear scale, where now the present epoch lies very near the origin. With greater than closure density the expansion becomes one which goes through at least one cycle and as figure 4 shows, in the one cycle plotted the maximum expansion occurs at $L = 3$ corresponding to $\sim 119 \times 10^9$ years, while the end of the ensuing collapse occurs at $\sim 238 \times 10^9$ years.

Some investigators appear to reject the concept of an open universe on philosophical grounds and would prefer a closed model. Since the best estimate of the present matter density, namely $\sim 0.06\ \rho_{cr}$, is much too low for closure, one might argue, for example, for a present radiation density, $\rho_{r''}$, high enough to yield closure, i.e., $\rho_{r''} \cong 0.94\ \rho_{cr} \cong 5.34 \times 10^{-30}$ gm/cm^3. This corresponds to a black-body radiation temperature of $\sim$28°K, which is in very serious disagreement with observation. Such a high value of $\rho_{r''}$ also leads to a much smaller matter density at one second elapsed time ($\sim$1,000 times less), well outside the bounds of what appears to be required in the early universe to synthesize the required amounts of deuterium and helium. If on the other hand we suppose that there is mass in the universe which is not now observable and which would raise the mean universal density above the critical value, then one would be faced with several questions. For example, there would then be the necessity of finding other explanations for the now-accepted ages of the elements, galaxies, and stars, since they would exceed the present age in this model. Moreover, one must deal somehow with the observed cosmic abundances of deuterium and helium, as well as the observed black-body radiation temperature, all of which appear to be mutually consistent in the open cosmological model discussed. Gott, Gunn, Schramm, and Tinsley (1975) point out that a present matter density of $\sim 0.06\ \rho_{cr}$ is in their view already larger than the mean total density of luminous matter observed in galaxies, and that there are strong, if not overriding, reasons to render improbable various types of undetected matter, be they small or large black holes, ionized intergalactic matter, etc., in quantity sufficient to yield a large enough mean mass density to reach even the margin of closure. Still, as we commented earlier, there is as yet some doubt that all the luminous matter in galaxies has in fact been accounted for.[7]

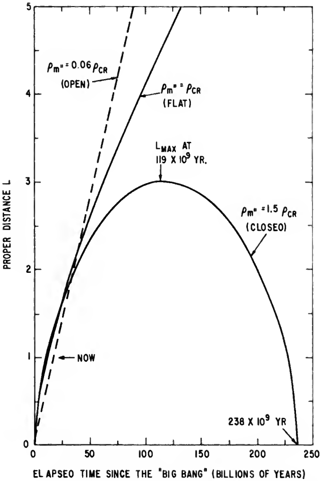

FIG. 4. Variation of the proper distance with elapsed time since the Big Bang for the "open," "flat," and "closed" model universes in figures 1, 2, and 3, plotted to show the behavior at longer times as well as a complete cycle for the "closed" case. For $L = 1$, which is "now," the open model gives $\sim 16.6 \times 10^9$ years, the flat model gives $\sim 11.8 \times 10^9$ years and the closed model gives $\sim 10.9 \times 10^9$ years.

It is beyond the scope of this discussion to consider variants of the simple Friedmann-Lemaître models illustrated above (see Weinberg, 1972). These variants include models which have various kinds of anisotropy, such as turbulence, shear, rotational motions, precursors of galactic magnetic fields, etc., during the radiation-dominated phase, as well as a class of models mentioned earlier that can be considered if the cosmological constant is re-introduced into the relativistic energy equation (see, for example, Roeder and Chambers, 1967; Weinberg, 1972). While these variants may prove to be interesting for such considerations as the development of structure during and after the crossover period, or provision of a "resting phase" during the expansion for galaxies to form, it may well be that on the simplest level the Big Bang as described by the open model in figure 1 may suffice as the basic representation of the evolution of the universe for some time to come. There are those, however, who feel that the evidence is not yet conclusive, although many such feelings were expressed before the Planck behavior of the relict cosmic microwave radiation at short wavelengths was as fully established as it now seems to be (Burbidge, 1971; Hoyle, 1973).

OBSERVATIONS OF THE BLACK-BODY RADIATION

At the time we made the black-body radiation prediction we did not pursue the question of its detectability. Moreover, because our prediction had been made initially in the context of Big Bang nucleosynthesis which, as mentioned, remains a viable theory for only the very lightest elements, those who might have suggested or made such appropriate microwave measurements seemed not aware of the possibility of its existence. In a paper in 1964 which apparently was not taken note of until some years later, Doroshkevich and Novikov (1964) suggested that one should look for such background radiation in the microwave region.

The first observations of the relict black-body radiation were made in 1965 by Penzias and Wilson, who, while calibrating the Bell Telephone Laboratories Holmdel horn-reflector system in order to study galactic synchrotron radiation, detected an excess isotropic antenna noise at a wavelength of 7.35 cm corresponding to a temperature[8] of ~3.5°K. The discovery was immediately interpreted to be relict black-body radiation by Dicke, Peebles, Roll, and Wilkinson (1965), who had been independently setting up equipment at Dicke's suggestion to look for relict radiation from a previous universal contraction. It was later realized that in an earlier paper by Dicke, Beringer, Kyle, and Vane (1946) an unexplained excess temperature of some 20°K detected by a radiometer of Dicke's design employed in studying atmospheric transmission might have been interpreted as an upper limit to the temperature of this background radiation. What is even more interesting in retrospect is that in the early 1940's McKellar (1941) interpreted observations made by Adams (1941) to indicate that the rotational excitation temperature of cyanogen (CN) radicals in interstellar space was ~2.3°K. However, the significance of this observation was not realized until after the measurements of Penzias and Wilson (see, for example, Thaddeus and Clauser, 1966; Thaddeus, 1972).

For the next several years observational evidence accumulated at wavelengths other than that used initially by Penzias and Wilson (1965). These data were generally in the long wavelength region of the Planck spectrum where the Rayleigh-Jeans approximation is valid. This approximation resembles a power law spectrum so familiar to radio astronomers in other spectral regions. Measurements near the peak of the Planck spectrum and at shorter wavelengths represent an extremely difficult region in which to make direct observations of the black-body radiation, and generally require that observations be made outside most of the atmosphere. The calculated black-body temperature obtained from studies of the populations of the lowest-lying rotationally excited states of interstellar CN refers to a wavelength of 0.264 cm, which lies near the peak of the Planck radiation curve. These measurements gave the first indications of deviations from a simple Rayleigh-Jeans power law (Thaddeus, 1972). Even before more recent observational confirmation began to accumulate in the short wavelength region, several investigators had inferred the short wavelength Planck spectrum from considerations of the interaction of γ-rays from the Crab Nebula and of high-energy cosmic rays with the black-body radiation. There now exists a growing body of evidence in the vicinity of the peak and at shorter wavelengths so that there appears to remain little doubt about the Planck nature of the black-body radiation.

We present in table 1 most of the presently available direct or inferred measurements of the black-body radiation (previous summaries are given by Penzias, 1972; Thaddeus, 1972; Peebles, 1971; Weinberg, 1972). The table includes names of the investigators, year of publication, wavelength or wavelength range of the observations, and the black-body temperature derived by the investigators from their intensity measurements) for a review of techniques see Penzias, 1968, 1972; Partridge, 1969; Roll and Wilkinson, 1966). The long wavelength measurements

---

[8] Penzias and Wilson (1968, 1972) later corrected this value to 3.3 ± 1.0°K.

TABLE 1

MEASUREMENTS OF THE BLACK-BODY TEMPERATURE[a]

Reference	Wavelength in cm	Black Body Temperature °K Inferred from Intensity
Howell and Shakeshaft (1967)	73.5	3.7 ± 1.2
	49.2	3.7 ± 1.2
Pelyushenko and Stankevich (1969)	30	2.5 ± 0.3
Penzias and Wilson (1967)	21.2	3.1 ± 1.0
Pelyushenko and Stankevich (1969)	20.9	2.5 ± 0.3
Howell and Shakeshaft (1966)	20.7	2.8 ± 0.6
Pelyushenko and Stankevich (1969)	15	2.5 ± 0.3
Penzias and Wilson (1965; Penzias, 1968)	7.35	3.3 ± 1.0
Roll and Wilkinson (1966, 1967)	3.2	3.0 ± 0.5
Stokes, Partridge, and Wilkinson (1967)	3.2	$2.69^{+0.16}_{-0.21}$
	1.58	$2.78^{+0.12}_{-0.17}$
Welch, Keachie, Thornton, and Wrixon (1967)	1.5	2.0 ± 0.8
Muehlner and Weiss (1973)[b]	1–0.19	$2.7^{+0.4}_{-0.2}$
	0.128	2.8 ± 0.2
	0.127	2.8 ± 0.2
	0.090	≦2.7
Ewing, Burke, and Staelin (1967)	0.924	3.16 ± 0.26
Wilkinson (1967)	0.856	$2.56^{+0.17}_{-0.22}$
Puzanov, Salomonovich, and Stankevich (1968)	0.82	2.9 ± 0.7
Blair, Beery, Edeskuty, Hiebert, Shipley, and Williamson (1971)[c]	0.6–0.08	$3.1^{+0.5}_{-2.0}$
Williamson, Blair, Caltin, Hiebert, Lloyd, and Romero (1973)[d]	0.6–0.03	2.7
Kisljakov, Chernyshev, Lebskii, Mal'tsev, and Serov (1971)	0.358	2.4 ± 0.7
Millea, McColl, Pederson, and Vernon (1971)	0.33	2.61 ± 0.25
Boynton, Stokes, and Wilkinson (1968)	0.33	$2.46^{+0.40}_{-0.44}$
Boynton and Stokes (1974)	0.33	$2.48^{+0.50}_{-0.54}$
Robson, Vickers, Huizinga, Beckmann, and Clegg (1974)	0.3–0.08	~2.8 (see figure 5)
Thaddeus (1966, 1972)[e]	0.264	2.78 ± 0.10
Peimbert (1968)	0.264	3.7 ± 0.7
Field and Hitchcock (1966)	0.264	3.2 ± 0.5
Woody, Mather, Nishioka, and Richards (1975; Richards, 1975)	0.25–0.059	$2.99^{+0.07}_{-0.14}$ (see figure 5)
Evans, Zuckerman, Morris, and Sato (1975)	0.2	2.9
Hegyi, Traub, and Carleton (1974)	0.132	$2.9^{+0.4}_{-0.5}$
Byram, Chubb, and Friedman (1970)[f]	~0.1	~2.7
Beckmann, Ade, Huizinga, Robson, Vickers, and Harries (1972)[g]	0.1–0.04	2.7

---

[a] Some early measurements, particularly at shorter wavelengths, have not been included because more precise later data suggest there were instrumental or observational anomalies in the early data. (For example, see Houck, Soifer, Harwit and Pipher (1972), who found better agreement with the data of others than in their earlier discordant work.)

[b] Result plotted in figure 5 at λ = 0.3 cm, equivalent to the mean wave number of their data range.

[c] Result plotted in figure 5 at λ = 0.14 cm, equivalent to the mean wave number of their data range.

[d] Result plotted in figure 5 at λ = 0.057 cm, equivalent to the mean wave number of their data range.

[e] Thaddeus (1972) has reviewed short wavelength measurements up to 1972.

[f] These data represent a wavelength and black-body temperature inferred from the probable interaction of black-body photons with the 1–10 Kev x-ray flux from Centaurus A.

[g] Result plotted in figure 5 at λ = 0.057 cm, equivalent to the mean wave number of their data range.

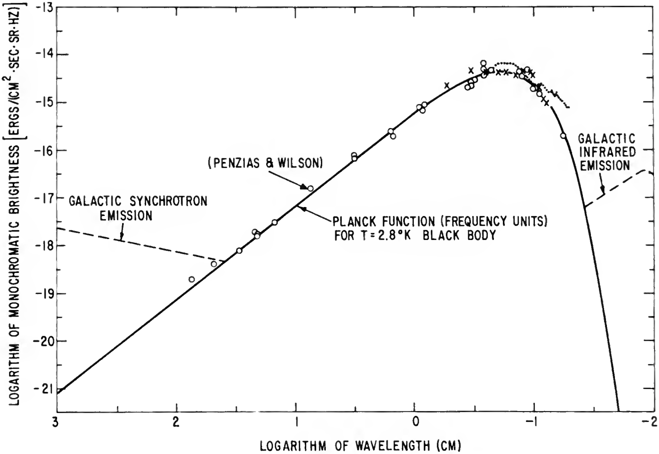

FIG. 5. Comparison of observations (see table 1) of the relict cosmic black-body radiation with the theoretical monochromatic brightness in ergs/(cm² sec sr Hz) as a function of wavelength, according to the Planck spectral distribution function for 2.8°K black-body. The maximum brightness occurs at 0.18 cm. The data point representing the original discovery by Penzias and Wilson is especially indicated. Some observations near the peak were recorded continuously over a range of wavelengths. Robson, Vickers, Huizinga Beckman, and Clegg averaged their observations to a unit wave number resolution and their data are shown by separated crosses. The data of Woody, Mather, Nishioka, and Richards covered a continuous range of wave numbers and are shown as a dotted line. The two long wavelength points due to Howell and Shakeshaft were derived by them from observation by subtracting out the galactic synchrotron background extrapolated into this wavelength region.

were made with ground-based radiometers, while the data near the peak of the radiation curve and at shorter wavelengths involved balloon- or rocket-borne experiments as well as temperatures derived from absorption in interstellar molecules such as the CN, CH, and CH$^+$ radicals and H$_2$CO (Thaddeus, 1972; Evans, Zuckerman, Morris, and Sato, 1975). For the sake of clarity we have plotted in figure 5 the data shown in table 1 without identifying the investigators, except for the original measurement of Penzias and Wilson, and without estimates of the precision of measurement. We have converted the listed derived temperatures to monochromatic brightness in the frequency interval $d\nu$ at ν and plotted the converted observations against the corresponding wavelength. Particular notice is called to the data of Woody, Mather, Nishioka and Richards (1975) which quite unequivocally show the turndown past the peak toward shorter wavelengths. Also shown is the interference of radiation from infrared galaxies on the short wavelength side as reported by Low and Tucker (1968) and the galactic synchrotron emission on the long wavelength side as reported by Turtle, Pugh, Kenderdine, and Pauliny-Toth (1962). The solid reference curve is the Planck black-body radiation distribution calculated for ~2.8°K, which is the suggested best value according to Thaddeus (1972) and Peebles (1971), and which differs only slightly from the value of ~2.7°K which is used elsewhere in this paper.

It appears rather clear from figure 5 that one would be hard pressed to argue against the relict black-body radiation interpretation of the observations, in view of the accuracy and consistency of the several different types of data over a wavelength ratio of about 1,800. Nevetheless various investigators have tried to construct, and properly so, rather *ad hoc* models consisting of the superposition of radiation from discrete sources, or of starlight from previous cycles of an oscillating universe (Davies, 1972), or of current starlight rethermalized by interstellar or intergalactic grains or molecules, etc. to provide alternative explanations of the observations (Hoyle and Wickramasinghe, 1968; Hoyle, Wickramasinghe, and Reddish, 1968; Shakeshaft and Webster, 1968; Partridge, 1969; Weinberg, 1972; Wickramasinghe, Edmunds, Chitre, Narliker and Ramandurai, 1975). The more recent confirmation of the radiation intensity at the peak and on the short wavelength side of the Planck distribution makes such alternatives appear rather artificial and many observers now accept the relict interpretation of the radiation and its corollary significance as evidence for a Big Bang cosmology.

A most recent and interesting exception to this interpretation is the view of Hoyle (1975), who states a concern about the remarkable isotropy (see below) displayed by the relict radiation between regions of the sky which have always been causally unconnected. As an alternate to the homogeneous Big Bang model he proposes an inhomogeneous cosmological model with no origin in the usual sense, made up of adjoining regions characterized by mass-fields of opposite sign, in which near the boundaries one has effectively a zero-mass-field Einstein-de Sitter model (the basic model of the steady-state theory). The time scale within each region depends on the changing scale of the metric, as do elementary particle masses. He argues that the entire observable universe is in the Einstein-de Sitter region, i.e., in the neighborhood of the interface between two regions, and that the relict radiation in our local space-time is the thermalized sum of radiant energy contributions from the conversion of hydrogen to helium in cosmic objects in an adjoining region of opposite mass-field sign (the "other side") for the last $\sim 150 \times 10^9$ years (as measured in our local time scale) plus some contribution of such energy from our own locale. The validity and ramifications of this model are not yet clear.

An additional important question is the extent to which the relict black-body radiation is isotropic (see Partridge, 1969; Peebles, 1971; Sciama, 1971; Weinberg, 1972, for more on this topic). If the homogeneous, isotropic Big Bang model of the universe is a correct description, then any anisotropy, i.e., any variation in intensity with direction in space, should reflect inhomogeneities at an earlier epoch when the radiation last interacted with matter as well as any anisotropy of the universal expansion. It should also reflect motions of the observer with respect to the distribution of matter at that epoch, or the introduction into the radiation field, subsequent to that time, of new radiant energy of different origin. Each of these is an intriguing question and we shall say a bit more about them later on. On the other hand, one would expect anisotropies in the relict radiation if the actual origin of the observed radiation was the superposition of current radiation from a large number of discrete sources, and was therefore not a cosmological phenomenon (see Layzer and Hively, 1973; Longair and Sunyaev, 1969; Parijskij, 1968; Rees, 1972; Rowan-Robinson, 1974; Smith and Partridge, 1970; Wolfe and Burbidge, 1969). In any event, measurements of anisotropy may provide important clues to the evolutionary history of the universe.

A considerable effort is now being devoted to such isotropy measurements (i.e., r.m.s. fluctuations in background temperature), and we have summarized most of the available data in table 2 and figure 6. All of the data, at whatever antenna beam width reported, indicate only upper limits to the anisotropy corresponding to the scale factors associated with those beam widths. The observed anisotropy limits are low enough to render very difficult the notion that the black-body spectrum arises from superposed radiation from a number of discrete sources (see above). The data have also imposed very severe restrictions on processes which might have added energy to the radiation field (Weymann, 1966; Zeldovich, Illarionov, and Sunyaev, 1972; Chan and Jones, 1975*b*), as well as on the size of fluctuations of whatever sort in the expanding universe prior to or during the early period when the universe switched from being radiation-dominated to being matter-dominated, i.e., the crossover period, when the opacity of the matter present essentially vanished (Alpher, Gamow, and Herman, 1967; Anile, 1974; Anile and Motta, 1974; Bahcall, Joss, and Lynds, 1973; Chan

TABLE 2

MEASUREMENTS OF ANISOTROPY IN THE COSMIC BLACK-BODY RADIATION[a]

Key	Reference	Wavelength in cm	Scale or Aperture	RMS departure from Isotropy in 10^{-3} °K
1.	Conklin and Bracewell (1967)	2.8	10 arc min	<3.6
2.	Penzias, Schraml and Wilson (1969)	0.35	1.27 arc min	<30
3.	Carpenter, Gulkis and Sato (1973)	3.56	2.3 arc min	<1.9
4.	Boynton and Partridge (1973)	0.35	80 arc sec	<4.3
5.	Parijskij (1973a)	4.0	12×40 arc min	<0.04
6.	Parijskij (1973b)	2.8	3 arc min − 1 arc deg	<0.08
7.	Stankevich (1974)	11.1	10 arc min	<0.42

[a] There are other data relevant to anisotropy which have not been identified in this table or in figure 6. These include large aperture measurements by Wilkinson and Partridge, described by Partridge (1969); early measurements at $\lambda = 3.4$ mm giving an upper limit of 54×10^{-3} °K at 2° aperture, reported by Epstein (1967); an upper limit of 100×10^{-3} °K at $\lambda = 7.35$ cm reported by Wilson and Penzias (1967); measurements showing no statistically significant anisotropy at $\lambda = 0.8$ cm by Boughn, Fram, and Partridge (1971); studies by Conklin (1969) and Henry (1971) who were seeking evidence for 12-hour or 24-hour periodicities in anisotropy of the black-body radiation, and whose results suggest upper limits of the order of $2 - 3 \times 10^{-3}$ °K. Schwartz (1970) found an upper limit of ~4 per cent in a 23° aperture survey of most of the sky in any inhomogeneity of the intensity of the diffuse x-ray background in the range 7.7 to 38 Kev, reflecting the isotropy of the black-body radiation if the x-rays arise from collisions of high-energy electrons with the black-body photons. Moreover, he inferred a higher upper limit to the 24-hour periodicity than was found by Conklin and Henry. A recent erratum by Parijskij regarding his datum point 6 suggests that the stated upper limit is too low by a factor six.

and Jones, 1975*a*; Chibosov and Ozernoy, 1969; Clutton-Brock, 1974; Collins and Hawking, 1973*a*, 1973*b*; Dautcourt, 1969; Gamow, 1948*a*; Rasband, 1971; Rowan-Robinson, 1974; Silk, 1968, 1974; Weinberg, 1971). Finally the upper limits are almost well enough defined to say something about the motion of the observing equipment with respect to the matter distribution at the time of last matter-radiation interaction.

IMPLICATIONS OF THE COSMIC BLACK-BODY RADIATION

During the decade since the first observation of the black-body radiation there has been an explosion of interest in pursuing the implications of this new and increasingly more firmly founded cosmological parameter. We are not in a position in this paper to do justice to even a small fraction of the now vast literature. However, we do wish at least to highlight some of the interesting ideas and directions which are being pursued.

Early on it was realized that the many varieties of cosmic radiation, be they particulate or electromagnetic, must interact with the 2.8°K photons. The very low-energy black-body photons appear to be quite energetic in the coordinates of high-energy cosmic rays, and significant effects should result from collisions. For example, it has been proposed that the isotropic cosmic x-ray background results from the inverse Compton effect due to interaction of cosmic-ray electrons with the 2.8°K photons (Schwartz, 1970). Not only should the energy spectrum of high-energy cosmic-ray protons be altered as a result of interactions with black-body photons, but also there should be an effective cutoff in the spectrum at energies above approximately 10^{20} eV. Measurements of the cosmic-ray electron spectrum, when interpreted in the framework of the galactic halo model, are found to be consistent with the expected interaction of high-energy electrons with black-body photons within the galaxy. Hillas and Ouldridge (1975) recently concluded that because the 2.8°K photons would truncate cosmic rays above $\sim 10^{20}$ eV if the cosmic rays were of intergalactic origin, and because there are now known to be 84 cosmic-ray events above $\sim 2 \times 10^{19}$ eV, which are, moreover, anisotropic in arrival direction, then it follows that the cosmic radiation must be galactic in origin. Kiraly, Osborne, White, and Wolfendale (1975) have argued that the statistics presented by Hillas and Ouldridge do not rule out some extragalactic contribution Stecker (1975) has proposed that the correlation between cosmic gamma-rays (produced by cosmic ray interactions with interstellargas) and the location of supernova remnants and gas clouds argues for a galactic origin of cosmic rays. In the reverse sense, the observation of cosmic radiation reaching the earth has been used to set upper limits to the intensity of black-body radiation at short wavelengths (Apparao, 1968; Cowsik, 1972). Various aspects of the interactions of cosmic radiation with the cosmic microwave background are discussed in the work of Bonometto, Luschin, and Margolungo (1974), Ginzburg (1970), Puget and Schatzman (1974), and Stecker (1973). For example, Puget and Schatzman suggest that their calculation of an upper limit for the interaction of starlight with the black-body photons rules out the "tired light" explanation for red shifts in the spectra of extra-galactic nebulae.

The plausibility given to the Big Bang model by the additional cosmological parameter represented by the black-body radiation has made it desirable to examine in more detail the earliest stages of the expansion during which there was interconversion of matter and radiation. The interest lies not only in understanding the synthesis of deuterium and helium but also in explaining in detail the properties of the medium in which processes involving elementary particles and radiation can be studied at the highest energies.[2] Insights may result into phenomena which are and will be emerging from the field of ultrahigh-energy physics.

For example, in this connection, during the expansion of the simple Big Bang model containing matter and radiation the specific entropy per baryon has a value which does not change with time throughout the expansion. We have already seen that several inferences may be drawn about the very early universe from the particular value of this quantity. It also appears that phenomena associated with the very early period influence the nature of the survival of any initial irregularities to the time of cross-over, e.g., neutrino viscosity provides a damping mechanism for fluctuations (Misner, 1967; Doroshkevich, Zeldovich, and Novikov, 1965; Weinberg, 1971). There are interesting questions yet to be resolved concerning the survival to the present time of neutrinos (Weinberg, 1972) and of gravitons in a manner analogous to the relict black-body radiation. Thus Matzner (1968) estimated the equivalent temperature of relict gravitons to be ~1.6°K, while Weinberg (1972) calculated a temperature of 1.9°K for relict neutrinos. Others have argued that observations of the number and type of relict neutrinos could yield great insights into the physics of the very early universe (Zeldovich, 1967).

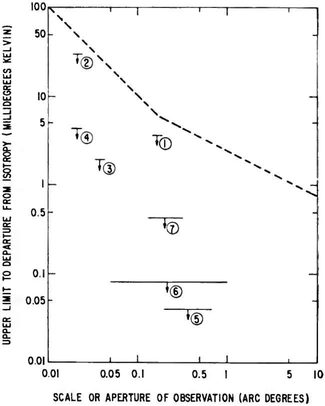

FIG. 6. Measurements of the upper limits to departures from isotropy (root mean square temperature fluctuation of the cosmic black-body radiation) as a function of the angular scale of the anisotropy (~ half-power beam width of observing antennas). The data points are numbered to correspond to table 2. Data points 5 through 7 represent a range of apertures. The dashed curve is an upper limit calculated by Conklin and Bracewell (1967) on the basis of their observation (point 1).

Another important implication of the black-body radiation anisotropy is that it may ultimately provide information on the scale of irregularities that may have existed in distant matter, again at the time of last interaction of the radiation with matter.[9] The existing data already give very strong restrictions on possible anisotropy in the early stages of the universe. In other words, the radiation and its isotropy provide for the first time a possible probe into the pregalactic character of the universe. The time of last interaction was identified quite early as the crossover time in the Big Bang model. Because of the uncoupling of matter and radiation (plasma recombination and the subsequent vanishing of opacity due to scattering and Bremsstrahlung) and the significant change in both the physical properties of the medium and also the rate of expansion of the universe during this period, it has been suggested that the formation of structure might have occurred thereafter (Alpher, Gamow, and Herman, 1967; Peebles, 1965, 1968, 1971).

---

[9] The origin of irregularities which might yield anisotropies includes, for example, adiabatic density perturbations (Peebles and Yu, 1970; Jones and Peebles, 1972), turbulent eddies (Gamow, 1954; Chibosov and Ozernoy, 1969), irregularities in the distribution of matter (Sachs and Wolfe, 1967), long wavelength gravitational radiation (Dautcourt, 1969; Rees, 1972; Burke, 1975) shear motions (Silk, 1974), radiation scattering after secondary

As has been pointed out by several investigators (see, for example, Sciama, 1972) an important consequence of the existence of the black-body photons is that it should be possible in principle to detect the motion of an observer with respect to the distribution of matter with which the radiation underwent its last scattering events, by measuring anisotropy in the radiation, particularly any 24-hour periodicity in anisotropy. It is estimated that the important contributions to the velocity of the observing equipment may be motion in our galaxy, motion of our galaxy with respect to the Local Group, and motion of the Local Group with respect to the Virgo Cluster, and that a 24-hour anisotropy of the order of $\sim 1 \times 10^{-3}$ °K might be significant. Sciama suggests that current periodic anisotropy measurements (Conklin, 1969; Henry, 1971) are not yet sufficiently precise to tie down what appears to be a relatively low net velocity (<300 km/sec). Finally, measurements of anisotropy of sufficient precision may also enable inference to be made of the existence of long wavelength gravitational waves, as discussed by Burke (1975).

An interesting aspect of now having the additional cosmological parameter represented by the black-body radiation is, of course, that it introduces yet another constraint which must be met by any hypothesized cosmological model. For example, the existence of such radiation is difficult to reconcile: with steady-state cosmology; with cosmologies that require large anisotropies prior to the time of crossover, i.e., in which the problem of galactic formation is handled by introducing the appropriate scale of fluctuations as an initial condition for the expansion; and with cosmologies in which rather special conditions are invoked to describe spatial separation of regions of matter and antimatter early in the expansion and which therefore may imply a significant scale of anisotropy. Furthermore the anisotropy limits may enable one to distinguish between general relativity models and such variants as the scalar-tensor model for which it has been shown that the expected scale of fluctuations leading to the present black-body radiation anisotropy should be significantly smaller than in the usual relativistic models (Dicke, 1968; Peebles and Yu, 1970).

Another consequence of the Big Bang model is the idea of using the time of matter-radiation density crossover as a "characteristic" time in describing the universe. Since 1937 Dirac (1938, 1972, 1974) has argued that one should look at the specification of models of the universe as requiring an implicit relation among certain large dimensionless ratios of quantities characteristic of the universe on the one hand and of elementary particles on the other hand. One of the quantities Dirac used is a characteristic time which he took to be the age of the universe. In order that all of the ratios considered vary with time in the same way he was led to conclude that the constant of gravitation G is not really constant, but rather varies slowly with the epoch. One approach to avoid this dilemma (Alpher and Gamow, 1968; Alpher, 1973), particularly as observational evidence for a time dependent G is in a state of flux (Van Flandern, 1974, 1975; Shapiro, 1974; various private communications), is to use the time of crossover, which is fixed for a given model, as the characteristic time. In this case none of the ratios vary with the epoch. Another approach to this dilemma is that of Harrison (1972) who points out that if the universe is indeed closed then the time of maximum expansion could also be used as a characteristic time. Thus, internally consistent large dimensionless ratios can be constructed with either of these characteristic times in the spirit of Dirac's views on large cosmic numbers, except that G need not be time-dependent.

---

heating and re-ionization (Sunyaev and Zeldovich, 1970*b*). Expansion anisotropy would be evidenced to some extent in anisotropy of the blackbody radiation (Partridge, 1969; Anile, 1974; Braus, 1975) and could lead to a polarization of the order of a tenth of the associated intensity anisotropy (Rees, 1968; Anile, 1974). The only polarization data known to the authors are those of Nanos (1974) who reports less than a few parts per thousand at $\lambda = 3.2$ cm. Recent suggestions that there is in fact evidence for an expansion anisotropy (Rubin, Ford and Rubin, 1973; Le Denmat and Vigier, 1975; Karoji and Moles, 1975) have been contradicted by Sandage and Tammann (1975*a*,*b*).

SUMMARY

The prediction of the existence of relict black-body radiation had its roots in our attempts to understand the synthesis of the chemical elements in an early stage of the simple Big Bang model of the universe. Prestellar nucleosynthesis required a model containing both matter and radiation at very high temperatures and densities and the survival of the black-body radiation in the universal expansion is a simple and natural consequence. The extensive observational confirmation of the Planck intensity distribution as well as the remarkable isotropy of this radiation has not only provided plausibility for the Big Bang model but has also stimulated investigations into a large number of associated phenomena ranging from the role of high energy particle-field interactions in the super-hot, dense, very early epoch of the universe to the mechanism of the formation of large-scale structures in the universe, i.e., galaxies and galactic clusters.

Details aside, what we now seem to know with some assurance is that there was an early state of the universe which was very hot and dense; that the present universe evolved from that state by expansion and cooling; that the most abundant elements in the universe other than hydrogen, namely deuterium and helium, probably were formed in this early epoch with the synthesis of the other elements being associated with stars which developed later in the structuring of the universe; that the conditions necessary to understand the formation of galaxies may well have been determined by the fundamental properties of matter on the microscale as these properties influenced the nature of the expanding universe during early times, i.e., there is a profound and fundamental interconnection between the largest and the smallest entities in the universe; and, finally, with somewhat less certainty, that the expanding universe is properly characterized as being open—that is to say, the singular event which has been called the Big Bang or the Primeval Fireball was, indeed, unique and we may never pass that way again.

> Gather ye rosebuds while ye may,
>   Old Time is still a-flying,
> And this same flower that smiles today
>   Tomorrow will be dying.
>
> Robert Herrick—*To the Virgins to Make Much of Time* (1648)

BIBLIOGRAPHY

Adams, W. S. 1941. "Results with the Coudé Spectrograph of the Mt. Wilson Observatory." *Astrophys. Jour.* **93**: pp. 11–23.

Alexanian, M. 1975. "The Fine-Structure Constant and Entropy in the Early Universe." In Press.

Alexanian, M., and F. Mejía-Lira. 1975. "Hadronic Nature of the Early Universe." In Press.

Alpher, R. A. 1948*a*. "Origin and Relative Abundance Distribution of the Elements." Thesis, George Washington University.

——. 1948*b*. "A Neutron-Capture Theory of the Formation and Relative Abundance of the Elements." *Phys. Rev.* **74**: pp. 1577–1589.

——. 1973. "Large Numbers, Cosmology and Gamow." *Amer. Scient.* **61**: pp. 52–58.

Alpher, R. A., H. Bethe, and G. Gamow. 1948. "The Origin of Chemical Elements." *Phys. Rev.* **73**: pp. 803–804.

Alpher, R. A., J. W. Follin, Jr., and R. Herman. 1953. "Physical Conditions in the Initial Stages of the Expanding Universe." *Phys. Rev.* **92**: pp. 1347–1361.

Alpher, R. A., and G. Gamow. 1968. "A Possible Relation Between Cosmological Quantities and the Characteristics of Elementary Particles." *Proc. Nat. Acad. Sci.* **61**: pp. 363–366.

Alpher, R. A., G. Gamow, and R. Herman. 1967. "Thermal Cosmic Radiation and the Formation of Protogalaxies." *Proc. Nat. Acad. Sci.* **58**: pp. 2179–2186.

Alpher, R. A., and R. Herman. 1948*a*. "Evolution of the Universe." *Nature* **162**: p. 774.

Alpher, R. A., and R. Herman. 1948*b*. "On the Relative Abundance of the Elements." *Phys. Rev.* **74**: pp. 1737–1742.

Alpher, R. A., and R. Herman. 1949. "Remarks on the Evolution of the Expanding Universe." *Phys. Rev.* **75**: pp. 1089–1095.

Alpher, R. A., and R. Herman. 1950. "Theory of the Origin and Relative Abundance Distribution of the Elements." *Rev. Mod. Phys.* **22**: pp. 153–212.

Alpher, R. A., and R. Herman. 1951. "Neutron-Capture Theory of Element Formation in an Expanding Universe." *Phys. Rev.* **84**: pp. 60–68.

Alpher, R. A., and R. Herman. 1953. "The Origin and Abundance Distribution of the Elements." *Ann. Rev. of Nuclear Sci.* (Palo Alto.) **2**: pp. 1–40.

Alpher. R. A., and R. Herman. 1972. "1. Reflections on 'Big Bang' Cosmology." ***Cosmology, Fusion and Other Matters: George Gamow Memorial Volume*** (F. Reines, Ed., Colorado), pp. 1–14.

Anile, A. M. 1974. "Anisotropic Expansion of the Universe and the Anisotropy and Linear Polarization of the Microwave Background." *Astrophys. and Space Sci.* **29**: pp. 415–426.

Anile, A. M., and S. Motta. 1974. "The Effect of a Linear Rotational Perturbation on the Isotropy of the Cosmic Background Radiation." *Astron. and Astrophys.* **32**: pp. 137–139.

Apparao, M. V. Krishna. 1968. "Upper Limit on Universal Microwave Radiation Below $\lambda = 1.7$ mm." *Nature* **219**: pp. 709–710.

Audouze, J., and B. M. Tinsley. 1974. "Galactic

Evolution and the Formation of the Light Elements." *Astrophys. Jour.* **192**: pp. 487–500.

Bahcall, J. N., P. C. Joss, and R. Lynds. 1973. "On the Temperature of the Microwave Background Radiation at a Large Redshift." *Astrophys. Jour. (Lett.)* **182**: pp. L95–L98.

Beckmann, J. E., P. A. R. Ade, J. S. Huizinga, E. I. Robson, D. G. Vickers, and J. E. Harries. 1972. "Limits to the Sub-millimeter Isotropic Background." *Nature* **237**: pp. 154–156.

Blair, A. G., J. G. Berry, F. Edeskuty, R. D. Hiebert, J. P. Shipley, and K. D. Williamson, Jr. 1971. "Measurement of the Far-Infrared Background Radiation in the Night Sky." *Phys. Rev. Lett.* **27**: pp. 1154–1157.

Bonometto, S. A., F. Lucchin, and P. Marcolungo. 1974. "Induced Pair Production and Opacity due to Black-Body Radiation." *Astron. and Astrophys.* **31**: pp. 41–46.

Boughn, S. P., D. M. Fram, and R. B. Partridge. 1971. "Isotropy of the Microwave Background at 8 Millimeter Wavelength." *Astrophys. Jour.* **165**: pp. 439–444.

Boynton, P. E., and R. B. Partridge. 1973. "Fine-Scale Anisotropy of the Microwave Background: An Upper Limit at $\lambda = 3.5$ mm." *Astrophys. Jour.* **181**: pp. 243–253.

Boynton, P. E., and R. A. Stokes. 1974. "Airborne Measurement of the Temperature of the Cosmic Microwave Background at 3.3 mm." *Nature* **247**: pp. 528–530.

Boynton, P. E., R. A. Stokes, and D. T. Wilkinson. 1968. "Primeval Fireball Intensity at $\lambda = 3.3$ mm." *Phys. Rev. Lett.* **21**: pp. 462–465.

Brans, C. H. 1975. "Propagation of Electromagnetic Polarization Effects in Anisotropic Cosmologies." *Astrophys. Jour.* **197**: pp. 1–4.

Burbidge, G. 1971. "Was There Really a Big Bang?" *Nature* **233**: pp. 36–40.

Burbidge, E. M., G. R. Burbidge, W. A. Fowler, and F. Hoyle. 1957. "Synthesis of the Elements in Stars." *Rev. Mod. Phys.* **29**: pp. 547–650.

Burke, W. L. 1975. "Large-Scale Random Gravitational Waves." *Astrophys. Jour.* **196**: pp. 329–334.

Byram, E. T., T. A. Chubb, and H. Friedman. 1970. "X-Ray Survey of Centaurus A." *Science* **169**: pp. 366–368.

Carlitz, R., S. Frautschi, and W. Nahm. 1973. "Implications of the Statistical Bootstrap Model for Cosmology and Galaxy Formation." *Astron. and Astrophys.* **26**: pp. 171–189.

Carpenter, R. L., S. Gulkis, and T. Sato. 1973. "Search for Small Scale Anisotropy in the 2.7°K Cosmic Background Radiation at a Wavelength of 3.56 Centimeters." *Astrophys. Jour. (Lett.)* **182**: pp. L61–L64.

Carr, B. J. 1975. "The Primordial Black Hole Mass Spectrum." In Press.

Carr, B. J., and S. W. Hawking. 1974. "Black Holes in the Early Universe." *Mon. Not. Roy. Astr. Soc.* **168**: pp. 399–415.

Chan, K. L., and B. J. T. Jones. 1975*a*. "Distortions of the 3°K Background Radiation Spectrum: Observational Constraints on the Early Thermal History of the Universe." *Astrophys. Jour.* **195**: pp. 1–11.

Chan, K. L., and B. J. T. Jones. 1975*b*. "Distortions of the Microwave Background Radiation Spectrum in the Submillimeter Wavelength Region." *Astrophys. Jour.* **198**: pp. 245–248.

Chandrasekhar, S., and L. R. Henrich. 1942. "An Attempt to Interpret the Relative Abundance of the Elements and Their Isotopes." *Astrophys. Jour.* **95**: pp. 288–298.

Chapline, G. F. 1975. "Cosmological Effect of Primordial Black Holes." *Nature* **253**: pp. 251–252.

Chibosov, G. V., and L. M. Ozernoy. 1969. "Angular Variations in the Background Radiation Caused by Macroscopic Motions in the Metagalactic Medium." *Astrophys. Lett.* **3**: pp. 189–193.

Clayton, D. D. 1968. *Principles of Stellar Evolution and Nucleosynthesis* (New York).

Clutton-Brock, M. 1974. "Why is the Universe Homogeneous?" *Astrophys. and Space Sci.* **30**: pp. 395–408.

Collins, C. B., and S. W. Hawking. 1973*a*. "The Rotation and Distortion of the Universe." *Mon. Not. Roy. Astr. Soc.* **162**: pp. 307–320.

Collins, C. B., and S. W. Hawking. 1973*b*. "Why is the Universe Isotropic?" *Astrophys. Jour.* **180**: pp. 317–334.

Conklin, E. K. 1969. "Velocity of the Earth with Respect to the Cosmic Background Radiation." *Nature* **222**: 971–972.

Conklin, E. K., and R. N. Bracewell. 1967. "Limits on Small Scale Variations in the Cosmic Background Radiation." *Nature* **216**: pp. 777–779.

Cowsik, R. 1972. "Limit on the Energy Density in the Submillimeter Background Radiation." *Nature PS* **239**: pp. 41–42.

Dautcourt, S. 1969. "Small-Scale Variations in the Cosmic Microwave Background." *Mon. Not. Roy. Astr. Soc.* **144**: pp. 255–278.

Davies, P. C. W. 1972. "Closed Time as an Explanation of the Black Body Background Radiation." *Nature* **240**: pp. 3–5.

de Sitter, W. 1930. "The Expanding Universe. Discussion of Lemaitre's Solution of the Equations of the Inertial Field." *Bull. Astron. Inst. Netherlands* **5**, 193: pp. 211–218.

——. 1931. "Some Further Computations Regarding Non-Static Universes." *Bull Astron. Inst. Netherlands* 6, 223: pp. 141–146.

Dicke, R. H. 1968. "Scalar-Tensor Gravitation and the Cosmic Fireball." *Astrophys. Jour.* **152**: pp. 1–24.

Dicke, R. H., R. Beringer, R. L. Kyle, and A. B. Vane. 1946. "Atmospheric Absorption Measurements with a Microwave Radiometer." *Phys. Rev.* **70**: pp. 340–348.

Dicke, R. H., P. J. E. Peebles, P. G. Roll, and D. T. Wilkinson. 1965. "Cosmic Black-Body Radiation." *Astrophys. Jour.* **142**: pp. 414–419.

Dirac, P. A. M. 1938. "New Basis for Cosmology." *Proc. Roy. Soc.* **A165**: pp. 199–208.

——. 1972. "The Variability of the Gravitational Constant." *Cosmology, Fusion and Other Matters: George Gamow Memorial Volume* (F. Reines, Ed., Colorado), pp. 56–59.

——. 1974. "Cosmological Models and the Large Numbers Hypothesis." *Proc. Roy. Soc.* **A338**: pp. 439–446.

Doroshkevich, A. G., and I. D. Novikov. 1964. "Mean Density of Radiation in the Metagalaxy and

Certain Problems in Relativistic Cosmology." *Sov. Phys.-Doklady* **9**: pp. 111–113.

Doroshkevich, A. G., Y. B. Zeldovich, and I. D. Novikov. 1968. "Weakly Interacting Particles in the Anisotropic Cosmological Model." *Sov. Phys.-J.E.T.P.* **26**: pp. 408–413.

Einstein, A. 1916. "Die Grundlage der allgemeinen Relativitätstheorie." *Ann. der Phys.* **49**: pp. 769–822.

——. 1917. "Kosmologische Betrachtungen zur Allegemeinen Relativitätstheorie." *Preuss. Akad. Wiss. Berlin.* **6**: pp. 142–152.

——. 1923. *The Principle of Relativity* (New York).

——. 1931. "Zur Kosmologische Problem der Allegemeinen Relativitätstheorie." *Preuss. Akad. Wiss. Berlin.* **12**: pp. 235–237.

——. 1955. *The Meaning of Relativity* (5th ed., Princeton Univ. Press).

Epstein, E. E. 1967. "On the Small-Scale Distribution at 3.4 mm Wavelength of the Reported 3°K Background Radiation." *Astrophys. Jour.* **148**: pp. L157–L158.

Evans, N. J., II, B. Zuckerman, G. Morris, and T. Sato. 1975. "Interstellar H_2CO. I. Absorption Studies, Dark Clouds and the Cosmic Background Radiation." *Astrophys. Jour.* **196**: pp. 433–456.

Ewing, M. S., B. F. Burke, and D. H. Staelin. 1967. "Cosmic Microwave Measurements at a Wavelength of 9.24 mm." *Phys. Rev. Lett.* **19**: pp. 1251–1253.

Field, G. B., H. Arp, and J. N. Bahcall. 1973. *The Redshift Controversy* (Reading, Mass.).

Field, G. B., and J. L. Hitchcock. 1966. "Cosmic Black-Body Radiation at $\lambda = 2.6$ mm (from Observations of Interstellar CN)." *Phys. Rev. Lett.* **16**: pp. 817–818.

Fowler, W. A. 1967. "Nucleosynthesis in Big and Little Bangs." *High Energy Physics and Nuclear Structure* (Amsterdam), pp. 203–225.

——. 1968. "The Empirical Foundations of Nucleosynthesis." *Origin and Distribution of the Elements* (L. H. Ahrens, Ed., New York), pp. 3–29.

——. 1971. "Facts and Fancies About 'Big Bang' Helium and Microwave Radiation." *Accademia Nazionale Dei Lincei* Quaderno N. 157: pp. 115–123.

Fowler, W. A., and W. E. Stephens. 1968. "Resource Letter OE-1 on the Origin of the Elements." *Amer. Jour. Phys.* **36**: pp. 289–302.

Friedman, A. 1922. "Über die Krümming des Raumes." *Zeits. f. Phys.* **10**: pp. 377–386.

——. 1924. "Über die Möglichkeit einer Welt mit Konstanter negativer Krümming des Raumes." *Zeits. f. Phys.* **21**: pp. 326–332.

Gamow, G. 1935. "Nuclear Transformations and the Origin of the Chemical Elements." *Ohio Jour. Sci.* **35**: pp. 406–413.

——. 1946. "Expanding Universe and the Origin of Elements." *Phys. Rev.* **70**: pp. 572–573.

——. 1948*a*. "The Origin of Elements and the Separation of Galaxies." *Phys. Rev.* **74**: pp. 505–506.

——. 1948*b*. "The Evolution of the Universe." *Nature* **162**: pp. 680–682.

——. 1949. "On Relativistic Cosmogony." *Rev. Mod. Phys.* **21**: pp. 367–373.

——. 1953. "Expanding Universe and the Origin of Galaxies." *K. Danske Vidensk. Selsk., mat.-fys. Medd.* **27**, 10: pp. 1–15.

——. 1954. "On the Formation of Protogalaxies in the Turbulent Primordial Gas." *Proc. Nat. Acad. Sci.* **40**: pp. 480–484.

——. 1956. "The Physics of the Expanding Universe." *Vistas in Astronomy* (A. Beers, Ed., New York) **2**: pp. 1726–1732.

——. 1967. "History of the Universe." *Science* **158**: pp. 766–769.

——. 1968. "Observational Properties of the Homogeneous and Isotropic Expanding Universe." *Phys. Rev. Lett.* **20**: pp. 1310–1312.

Ginzburg, V. L. 1970. "Origin of Cosmic Rays. 1. Introduction. Metagalactic Models." *Comm. on Astrophys. and Space Sci.* **2**: pp. 1–5.

Gisler, G. R., E. R. Harrison, and M. J. Rees. 1974. "Variations in the Primordial Helium Abundance." *Mon. Not. Roy. Astr. Soc.* **166**: pp. 663–671.

Gott, J. R., III, J. E. Gunn, D. N. Schramm, and B. M. Tinsley. 1974. "An Unbound Universe?" *Astrophys. Jour.* **194**: pp. 543–553.

Gunn, J. E., and B. M. Tinsley. 1975. "An Accelerating Universe?" Calif. Inst. of Tech. Preprint OAP-411, July.

Harrison, E. R. 1972. "The Cosmic Numbers." *Physics Today* **25**, 12: pp. 30–34.

——. 1973. "Standard Model of the Early Universe." *Ann. Rev. of Astron. and Astrophys.* (Palo Alto.) **11**: pp. 155–186.

Hegyi, D. J., W. A. Traub, and N. P. Carleton. 1974. "Cosmic Background Radiation at 1.32 Millimeters." *Astrophys. Jour.* **190**: pp. 543–544.

Henry, P. S. 1971. "Isotropy of the 3°K Background." *Nature* **231**: pp. 516–518.

Hillas, A. M., and M. Ouldridge. 1975. "Cosmic Rays and the Galaxy." *Nature* **253**: pp. 609–610.

Houck, J. R., B. T. Soifer, M. Horwit and J. L. Pipher. 1972." The Far-Infrared and Submillimeter Background." *Astrophys. Jour.* **178**: pp. L29–L33.

Howell, T. F., and J. R. Shakeshaft. 1966. "Measurement of the Minimum Cosmic Background Radiation at 20.7-cm Wavelength." *Nature* **210**: pp. 1318–1319.

Howell, T. F., and J. R. Shakeshaft. 1967. "Spectrum of the 3°K Cosmic Microwave Radiation." *Nature* **216**: pp. 753–754.

Hoyle, F. 1973. "The Origin of the Universe." *Quart. Jour. Roy. Astr. Soc.* **14**: pp. 278–287.

——. 1975. "On the Origin of the Microwave Background." *Astrophys. Jour.* **196**: pp. 661–670.

Hoyle, F., and N. C. Wickramasinghe. 1968. "Condensation of Dust in Galactic Explosions." *Nature* **218**: pp. 1126–1127.

Hoyle, F., N. C. Wickramasinghe, and V. C. Reddish. 1968. "Solid Hydrogen and the Microwave Background." *Nature* **218**: pp. 1124–1126.

Hubble, E. 1929. "A Relation Between Distance and Radial Velocity Among Extra-Galactic Nebulae." *Proc. Nat. Acad. Sci.* **15**: pp. 168–173.

——. 1936. *The Realm of the Nebula* (New Haven), chap. V.

Jones, B. T. J., and P. J. E. Peebles. 1972. "Chaos in Cosmology." *Comm. on Astrophys. and Space Sci.* **4**: pp. 121–128.

Karoji, H., and M. Moles. 1975. "Les Galaxies de Markarian et l'Anisotropie Angulaire de la 'Constante' de Hubble." *C. R. Acad. Sc. Paris.* **280**: pp. 609–612.

Kiraly, P., L. Osborne, M. White and A. W. Wolfendale. 1975. "Origin of Ultra High Energy Cosmic Rays." *Nature* **255**: pp. 619–620.

Kislyakov, A. G., V. I. Chernyshev, Y. I. Lebskii, V. A. Mal'tsov, and N. V. Serov. 1971. "The Effective Temperature of Cosmic Black Body Radio Emission at 3.58 mm." *Sov. Astron.-A.J.* **15**: pp. 29–34.

Layzer, D., and R. Hively. 1973. "Origin of the Microwave Background." *Astrophys. Jour.* **179**: pp. 361–369.

Le Denmat, G., and J.-P. Vigier. 1975. "Les Supernovae de Type I et l'Anisotropie de la 'Constante' de Hubble." *C. R. Acad. Sc. Paris.* **280**: pp. 609–612.

Lemaître, G. 1931. "Homogeneous Universe of Constant Mass and Increasing Radius." *Mon. Not. Roy. Astr. Soc.* **91**: pp. 483–490.

——. 1950. *The Primeval Atom. An Essay on Cosmogony* (New York).

Longair, M. S., and M. J. Rees. 1972. "The Counts of Radio Sources." *Comm. on Astrophys. and Space Sci.* **4**: pp. 79–93.

Longair, M. S., and R. A. Sunyaev. 1969. "Fluctuations in the Microwave Background Radiation." *Nature* **223**: pp. 719–721.

Low, F. J., and W. H. Tucker. 1968. "Contribution of Infrared Galaxies to the Cosmic Background." *Phys. Rev. Lett.* **21**: pp. 1538–1541.

McCrea, W. H. 1968. "Cosmology After Half a Century." *Science* **160**: pp. 1295–1299.

——. 1970. "Cosmology Today." *Amer. Scien.* **58**: pp. 521–527.

McKellar, A. 1941. "Molecular Lines from the Lowest States of Diatomic Molecules Composed of Atoms Probably Present in Interstellar Space." *Publs. Dominion Astrophys. Obs. Victoria* **7**: pp. 251–272.

Matzner, R. A. 1968. "On the Present Temperature of Primordial Black-Body Gravitational Radiation." *Astrophys. Jour.* **154**: pp. 1123–1126.

Millea, M. F., M. McColl, R. J. Pederson, and F. L. Vernon, Jr. 1971. "Cosmic Background Radiation at $\lambda = 3.3$ mm." *Phys. Rev. Lett.* **26**: pp. 919–922.

Misner, C. W. 1967. "Neutrino Viscosity and the Isotropy of Primordial Black-body Radiation." *Phys. Rev. Lett.* **19**: pp. 533–535.

Muehlner, D., and R. Weiss. 1973. "Balloon Measurements of the Far-Infrared Background Radiation." *Phys. Rev. D.* **7**: pp. 326–344.

Munitz, M. K. (Ed.). 1957. *Theories of the Universe* (Glencoe, Ill.).

Nanos, G. P., Jr. 1974. "Polarization of the Blackbody Radiation at 3.2 cm." Thesis, Princeton University.

Napier, W. M., and B. N. G. Guthrie. 1975. "Black Dwarf Stars as Missing Mass in Clusters of Galaxies." *Mon. Not. Roy. Astr. Soc.* **170**: pp. 7–14.

Noerdlinger, P. D. 1973. "Primordial 2.7° Radiation as Evidence Against Secular Variation of Planck's Constant." *Phys. Rev. Lett.* **30**: pp. 761–762.

North, J. D. 1965. *The Measure of the Universe: A History of Modern Cosmology* (Oxford).

Novikov, I. D., and Y. B. Zeldovich. 1973. "Physical Processes near Cosmological Singularities." *Ann. Rev. of Astron. and Astrophys.* (Palo Alto) **11**: pp. 387–412.

Ostriker, J. P., P. J. E. Peebles, and A. Yahil. 1974. "The Size and Mass of Galaxies and the Mass of the Universe." *Astrophys. Jour.* (*Lett.*) **193**: pp. L1–L4.

Parijskij, Y. N. 1968. "On the Origin of the 'Black Body' Radiation of the Universe." *Sov. Astr.-A. J.* **12**: pp. 219–224.

——. 1973*a*. "New Limit of Fluctuations of Relict Emission of the Universe." *Sov. Astr.-A. J.* **17**: pp. 291–294.

——. 1973*b*. "New Limits on Small-Scale Irregularities of Black-body Radiation." *Astrophys. Jour.* (*Lett.*) **180**: pp. L47–L48; erratum, **188**: p. L113.

Partridge, R. B. 1969. "The Primeval Fireball Today." *Amer. Scien.* **57**: pp. 37–74.

Peebles, P. J. E. 1965. "The Black Body Radiation Content of the Universe and the Formation of Galaxies." *Astrophys. Jour.* **142**: pp. 1317–1326.

——. 1966. "Primordial Helium Abundance and the Primordial Fireball II." *Astrophys. Jour.* **146**: pp. 542–552.

——. 1968. "Recombination of the Primeval Plasma." *Astrophys. Jour.* **153**: pp. 1–12.

——. 1971. *Physical Cosmology* (Princeton).

Peebles, P. J. E., and J. T. Yu. 1970. "Primeval Adiabatic Perturbation in an Expanding Universe." *Astrophys. Jour.* **162**: pp. 815–836.

Peimbert, M. 1968. "Interstellar Molecular Lines in A Stars." *Bol. Obs. Tonantzintla y Tacubaya* **4**, 30: pp. 233–239.

Pelyushenko, S. A., and K. S. Stankevich. 1969. "Absolute Temperature Measurements of the Cosmic Radio Emission of the Sky in the Decimeter Range." *Sov. Astr.-A. J.* **13**: pp. 223–225.

Penzias, A. A. 1968. "Measurement of Cosmic Microwave Background Radiation." *IEEE Trans. Microwave Theory and Techniques* **MTT-16**, 9: pp. 608–611.

——. 1972. "3. Cosmology and Microwave Astronomy." *Cosmology, Fusion and Other Matters: George Gamow Memorial Volume* (F. Reines, Ed., Colorado), pp. 29–47.

Penzias, A. A., J. Schraml, and R. W. Wilson. 1969. "Observational Constraints on a Discrete Source Model to Explain the Microwave Background." *Astrophys. Jour.* (*Lett.*) **157**: pp. L49–L51.

Penzias, A. A., and R. W. Wilson. 1965. "A Measurement of Excess Antenna Temperature at 4080 Mc/S." *Astrophys. Jour.* **142** pp. 419–421.

Penzias, A. A., and R. W. Wilson. 1967. "Measurement of the Background Temperature at 1415 Mhz." *Astron. Jour.* **72**: p. 315.

Puget, J. L., and E. Schatzman. 1974. "Upper Limit on Photon-Photon Interaction from Physical Cosmology." *Astron. and Astrophys.* **32**: pp. 477–478.

Puzanov, V. I., A. E. Salomonovich, and K. S. Stankevich. 1968. "The Measurement of Black Body Temperature of Relict Background Radiation at Wavelength of 8.2 mm." *Sov. Astr.-A. J.* **11**: pp. 905–906.

Rasband, S. 1971. "Expansion Anisotropy and the Spectrum of the Cosmic Background Radiation." *Astrophys. Jour.* **170**: pp. 1–15.

Rees, M. J. 1968. "Polarization and Spectrum of the Primeval Radiation in an Anisotropic Universe." *Astrophys. Jour.* **153**: pp. L1–L6.

——. 1971. "The Cosmic Background Radiation: Some Recent Developments." *Highlights of Astron.* **2**: pp. 757–767.

——. 1972. "Origin of the Cosmic Microwave Background Radiation in a Chaotic Universe." *Phys. Rev. Lett.* **28**: pp. 1669–1671.

REEVES, H. 1972. "Densities of Baryons and Neutrinos in the Universe from an Analysis of Big Bang Nucleosynthesis." *Phys. Rev. D.* **6**: pp. 2363–2368.

RICHARDS, P. L. 1975. "A Measurement of the Spectrum of the Submillimeter Cosmic Blackbody Radiation." *Bull Amer. Phys. Soc.* **20**, 4: p. 540.

ROBSON, E. I., D. G. VICKERS, J. S. HUIZINGA, J. E. BECKMAN, and P. E. CLEGG. 1974. "Spectrum of the Cosmic Background Radiation Between 3 mm and 800 μm." *Nature* **251**: pp. 591–592.

ROEDER, R. C., and R. H. CHAMBERS. 1967. "Blackbody Radiation and the Eddington-Lemaître Universe." *Nature* **216**: pp. 774–775.

ROLL, P. G., and D. T. WILKINSON. 1966. "Measurement of Cosmic Background Radiation at 3.2 cm Wavelength—Support for Cosmic Black-Body Radiation." *Phys. Rev. Lett.* **16**: pp. 405–407.

ROLL, P. G., and D. T. WILKINSON. 1967. "Measurement of Cosmic Background Radiation at 3.2-cm Wavelength." *Ann. Phys.* **44**: pp. 289–321.

ROWAN-ROBINSON, M. 1974. "A Discrete Source Model of the Microwave Background." *Mon. Not. Roy. Astr. Soc.* **168**: pp. 45P–50P.

RUBIN, V. C., W. K. FORD, JR., and J. S. RUBIN. 1973. "A Curious Distribution of Radial Velocities of ScI Galaxies with $14.0 \leq m \leq 15.0$." *Astrophys. Jour.* **183**: pp. L111–L115.

RYLE, M. 1968. "The Counts of Radio Sources." *Ann. Rev. of Astron. and Astrophys.* (Palo Alto) **6**: pp. 249–266.

SACHS, R. K., and A. M. WOLFE. 1967. "Perturbations of a Cosmological Model and Angular Variations of the Microwave Background." *Astrophys. Jour.* **147**: pp. 73–89.

SANDAGE, A. R. 1972. "Distance to the Galaxies: The Hubble Constant, the Friedman Time, and the Edge of the World." *Quar. Jour. Roy. Astron. Soc.* **13**: pp. 282–296.

SANDAGE, A., and G. A. TAMMANN. 1975*a*. "Steps Toward the Hubble Constant. V. The Hubble Constant from Nearby Galaxies and the Regularity of the Local Velocity Field." *Astrophys. Jour.* **196**: pp. 313–328.

SANDAGE, A., and G. A. TAMMANN. 1975*b*. "Steps Toward the Hubble Constant. IV. The Hubble Constant Determined from Redshifts and Magnitudes of Remote ScI Galaxies: The Value of q_0." *Astrophys. Jour.* **197**: pp. 265–280.

SCHWARTZ, D. A. 1970. "The Isotropy of the Diffuse Cosmic X-Rays Determined by OSO-III." *Astrophys. Jour.* **162**: pp. 439–444.

SCIAMA, D. W. 1971. *Modern Cosmology* (Cambridge).

——. 1972. "Eppur Si Muove." *Comm. on Astrophys. and Space Sci.* **4**: pp. 35–39.

SEARLE, L., and W. L. W. SARGENT. 1972. "The Observational Status of Cosmological Helium." *Comm. on Astrophys. and Space Sci.* **4**: pp. 59–64.

SHAKESHAFT, J. R., and A. S. WEBSTER. 1968. "Microwave Background in a Steady State Universe." *Nature* **217**: pp. 339–340.

SHAPIRO, I. I. 1974. Paper delivered to 5th Cambridge Conference on Relativity, June 10.

SILK, J. 1968. "Cosmic Black Body Radiation and Galaxy Formation." *Astrophys. Jour.* **151**: pp. 459–471.

——. 1974. "The Primordial Generation of Random Shear Motions and Small-Scale Angular Anisotropy in the Microwave Background Radiation." *Astrophys. Jour.* **194**: pp. 215–222.

SISTERÓ, R. F. 1973. "Cosmological Hadronic Fireball." *Astrophys. and Space Sci.* **20**: pp. 19–25.

SMIRNOV, Y. N. 1965. "Hydrogen and He^4 Formation in the Prestellar Gamow Universe." *Sov. Astr.-A. J.* **8**: pp. 864–867.

SMITH, M. G., and R. B. PARTRIDGE. 1970. "Can Discrete Sources Produce the Cosmic Microwave Radiation?" *Astrophys. Jour.* **159**: pp. 737–743.

STANKEVICH, K. S. 1974. "Fine Scale Temperature Variations in the 11.1 cm Cosmic Background Radiation." *Sov. Astr.-A. J.* **18**: pp. 126–127.

STAUFFER, D. 1972. "Temperature Maximum of the Early (Hadron) Universe." *Phys. Rev. D.* **6**: pp. 1797–1798.

STECKER, F. W. 1973. "Ultrahigh Energy Photons, Electrons, and Neutrinos, the Microwave Background, and the Universal Cosmic Ray Hypothesis." *Astrophys. and Space Sci.* **20**: pp. 47–57.

——. 1975. "Origin of Cosmic Rays." *Phys. Rev. Lett.* **35**: pp. 188–191.

STEWART, J. M. 1969. "Non-Equilibrium Processes in the Early Universe." *Mon Not. Roy. Astr. Soc.* **145**: pp. 347–356.

STOKES, R. A., R. B. PARTRIDGE, and D. T. WILKINSON. 1967. "New Measurements of the Cosmic Microwave Background at $\lambda = 3.2$ cm and $\lambda = 1.58$ cm—Evidence in Support of a Blackbody Spectrum." *Phys. Rev. Lett.* **19**: pp. 1199–1202.

SUNYAEV, R. A., and Y. B. ZELDOVICH. 1969. "An Open Universe?" *Comm. on Astrophys. and Space Sci.* **1**: pp. 159–163.

SUNYAEV, R. A., and Y. B. ZELDOVICH. 1970*a*. "Small Scale Entropy and Adiabatic Density Perturbations—Antimatter in the Universe." *Astrophys. and Space Sci.* **9**: pp. 368–382.

SUNYAEV, R. A., and Y. B. ZELDOVICH. 1970*b*. "Small Scale Fluctuations of Relic Radiation." *Astrophys. and Space Sci.* **7**: pp. 3–19.

SUNYAEV, R. S., and Y. B. ZELDOVICH. 1972. "The Observation of Relic Radiation as a Test of the Nature of X-Ray Radiation from the Clusters of Galaxies." *Comm on Astrophys. and Space Sci.* **4**: pp. 173–178.

SZALAY, A. S., and G. MARX. 1974. "Limits on the Rest Masses from Big Bang Cosmology." *Acta Phys. Acad. Sci. Hung.* **35**: pp. 113–129.

TAYLER, R. J. 1972. *The Origin of the Chemical Elements* (London).

THADDEUS, P. 1972. "The Short-Wavelength Spectrum of the Microwave Background." *Ann. Rev. of Astron. and Astrophys.* (Palo Alto) **10**: pp. 305–334.

THADDEUS, P., and J. F. CLAUSER. 1966. "Cosmic Microwave Radiation at 2.63 mm from Observations of Interstellar CN." *Phys. Rev. Lett.* **16**: pp. 819–822.

TINSLEY, B. M. 1975. "Will the Universe Expand Forever?" *Bull. Amer. Phys. Soc.* **20**, 4: p. 540.

TOLMAN, R. C. 1931. "On the Theoretical Requirements for a Periodic Behavior of the Universe." *Phys. Rev.* **38**: pp. 1758–1771.

——. 1934. *Relativity, Thermodynamics and Cosmology* (Oxford).

Tomita, K. 1972. "Primordial Irregularities in the Early Universe." *Prog. Theor. Phys. (Japan)* **48**: pp. 1503–1516.

——. 1973. "Element Formation in a Chaotic Early Universe." *Prog. Theor. Phys. (Japan)* **50**: pp. 1285–1301.

Tryon, E. P. 1973. "Is the Universe a Vacuum Fluctuation?" *Nature* **246**: pp. 396–397.

Turtle, A. J., J. F. Pugh, S. Kenderdine, and I. I. K. Pauling-Toth. 1962. "The Spectrum of the Galactic Radio Emission. I. Observations of Low Resolving Power." *Mon. Not. Roy. Astr. Soc.* **124**: pp. 297–312.

Van Flandern, T. C. 1975*a*. "A Determination of the Rate of Change of G." *Mon. Not. Roy. Astr. Soc.* **170**: pp. 333–342.

——. 1975*b*. "A New Measurement of the Rate of Change of G." *Bull. Amer. Phys. Soc.* **20**, 4: p. 543.

von Weizsäcker, C. F. 1938. "Über Elementumwandlungen im Innern der Sterne." *Physik. Zeits.* **39**: pp. 633–645.

Wagoner, R. V. 1973. "Big Bang Nucleosynthesis Revisited." *Astrophys. Jour.* **179**: pp. 343–360.

Wagoner, R. V., W. A. Fowler, and F. Hoyle. 1967. "On the Synthesis of Elements at Very High Temperatures." *Astrophys. Jour.* **148**: pp. 3–49.

Weinberg, S. 1971. "Entropy Generation and the Survival of Protogalaxies in an Expanding Universe." *Astrophys. Jour.* **168**: pp. 175–194.

——. 1972. *Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity* (New York).

Welch, W. J., S. Keachie, D. D. Thornton, and G. Wrixon. 1967. "Measurement of the Cosmic Microwave Background Temperature at 1.5 cm Wavelength." *Phys. Rev. Lett.* **18**: pp. 1068–1070.

Weymann, R. 1966. "The Energy Spectrum of Radiation in the Expanding Universe." *Astrophys. Jour.* **145**: pp. 560–571.

Wickramasinghe, N. C., M. G. Edmunds, S. M. Chitre, J. V. Narliker and S. Ramadurai. 1975. "A Dust Model for the Cosmic Microwave Background." *Astrophys. and Space Sci.* **35**: pp. L9–L13.

Williamson, K. D., A. G. Blair, L. L. Caltin, R. D. Hiebert, E. G. Lloyd, and H. V. Romero. 1973. "Night Sky Background Measurement at 6 to 0.3 mm." *Nature PS* **241**: pp. 79–80.

Wilkinson, D. T. 1967. "Measurement of the Cosmic Microwave Background at 8.56 mm Wavelength." *Phys. Rev. Lett.* **19**: pp. 1195–1198.

Wilson, R. W., and A. A. Penzias. 1967. "Isotropy of Cosmic Background Radiation at 4080 Megahertz." *Science* **156**: pp. 1100–1101.

Wolfe, A. M., and G. R. Burbidge. 1969. "Discrete Source Models to Explain the Microwave Background Radiation." *Astrophys. Jour.* **156**: pp. 345–372.

Woody, D. P., J. C. Mather, N. S. Nishioka, and P. L. Richards. 1975. "A Measurement of the Spectrum of the Submillimeter Cosmic Background." *Phys. Rev. Lett.* **34**: pp. 1036–1039.

Zeldovich, Y. B. 1965. "Survey of Modern Cosmology." *Advances in Astr. and Astrophys.* (Z. Kopal, Ed., New York) **3**: pp. 241–379.

——. 1967. "The 'Hot' Model of the Universe." *Sov. Phys.-Uspekhi* **9**: pp. 602–617.

——. 1970. "The Universe as a Hot Laboratory for the Nuclear and Particle Physicist." *Comm. on Astrophys. and Space Sci.* **2**: pp. 12–17.

——. 1972. "A Hypothesis, Unifying the Structure and the Entropy of the Universe." *Mon. Not. Roy. Astr. Soc.* **160**: pp. 1P–3P.

Zeldovich, Y. B., A. F. Illarionov, and R. A. Sunyaev. 1972. "The Effect of Energy Release on the Emission Spectrum in a Hot Universe." *Sov. Phys.-J.E.T.P.* **35**: pp. 643–648.

THE NATIONAL GALLERY OF ART: AN AMERICAN EXPERIMENT

PAUL MELLON

President, National Gallery of Art

(Read April 25, 1975)

In March, 1937, the United States government accepted the gift of an outstanding art collection, as well as certain funds to build and endow a gallery for its display and its future expansion.

The donor was my father, Andrew W. Mellon. He had begun collecting as a young man when, touring Europe with his friend Henry Clay Frick long before the turn of the century, he acquired his first painting. It cost one thousand dollars, and he brought it back to Pittsburgh. His brothers and his business associates were greatly dismayed! They questioned the extravagance of such a large outlay for a single picture. But he went on to fill his Pittsburgh house with paintings he enjoyed, principally Dutch, English, and Barbizon School landscapes and portraits. They refreshed him with glimpses of a green and sunlit world far from the murky atmosphere of his home city.

When he moved to Washington in 1921 to become secretary of the treasury, his pictures filled an apartment on Massachusetts Avenue. He continued to buy works of art for his own pleasure. But as his collection grew, so did the idea of establishing a great national collection for public enjoyment and benefit.

My father had the resources and the determination to make this dream a reality. He had a special assistant in the Treasury, a young man named David Finley, a lawyer with a passion for and a considerable knowledge of art history. He discussed his plans with Finley, and asked him to help with the organization of the new gallery and eventually to become its first director. From that time until his retirement in 1956, David Finley was intimately connected with every phase of the growth and development of the National Gallery of Art.

He began by assisting my father in broadening the scope of the collection, which now was to serve a larger purpose than that of personal enjoyment. For many years my father had bought only from Knoedler's, now he began to make purchases also from Joseph Duveen, later Lord Duveen, whom he had met in London. These two New York dealers were the only ones from whom he ever bought, and because he was their most important client, they invariably gave him first option.

The idea that Duveen was the only, or principal supplier of pictures to the collection has often been greatly exaggerated. There is an apocryphal story of the lady who exclaimed on first entering the new National Gallery—"How simply Duveen!"

Charles Henschel or Carman Messmore of Knoedler's, and Lord Duveen himself, would bring paintings to Washington and hang them on the walls of our apartment, so that my father could make up his mind at leisure. He would ask the opinion of others, but the final selection, sometimes carefully pondered for a considerable period of time, was always his own.

In 1930, with the decisiveness characteristic of his business dealings, he seized a unique opportunity. In a cloak and dagger atmosphere, and by a sequence of events too complicated to describe here—(it is clearly set out in David Finley's book *A Standard of Excellence* and in John Walker's *Self-Portrait with Donors*), it became known that paintings from the Hermitage Gallery in Leningrad might become available. The Soviets needed to raise money. Knoedler's, in partnership with the London firm of Colnaghi, approached my father with the proposal that if he would back them financially they would offer him first choice of anything they bought—to which he agreed. In the end he took all the paintings they purchased, thus acquiring at one stroke twenty-one masterpieces at a cost of perhaps one-fifth of their value today. The purchase remained secret, and the paintings were stored until the announcement of their inclusion in the gift to the National Gallery.

My father's appointment in 1932 as ambassador to the Court of St. James's positively stimulated the development of his plans for a

PROCEEDINGS OF THE AMERICAN PHILOSOPHICAL SOCIETY, VOL. 119, NO. 5, OCTOBER 1975

national gallery in Washington. Frequent visits to England since his first trip with Frick had made him very familiar with the National Gallery in London, whose building and its contents he now studied with closer attention. He had always admired the dignity of its style and the high quality of its contents; and its administration, partly financed by the Treasury and partly by donations from private individuals, corresponded somewhat with what he had in mind for Washington.

When he returned from England, he took the final steps toward the realization of his goal. His collection was rounded out by the purchase from Duveen of twenty-six paintings, largely of the Italian Schools, and eighteen sculptures. He also bought the Thomas B. Clarke Collection of American portraits, recognizing that, although these were uneven in quality, some of them could later take their place in an American national portrait gallery.

His collection now illustrated the development of Western art through seven centuries, and he was ready to offer it to the nation.

He wrote to President Franklin D. Roosevelt in December, 1936:

> My dear Mr. President:
>
> Over a period of many years I have been acquiring important and rare paintings and sculpture with the idea that ultimately they would become the property of the people of the United States and be made available to them in a national art gallery to be maintained in the city of Washington for the purpose of encouraging and developing a study of the fine arts.

He went on to a provision most important for the future growth of the Gallery;

> Such a gallery would be for the use and benefit of the general public; and it is my hope that it may attract gifts from other citizens who may in the future desire to contribute works of art of the highest quality to form a great national collection. In connection, therefore, with the intended gift, I shall stipulate that the proposed building shall not bear my name, but shall be known as The National Art Gallery or by such other name as may appropriately identify it as a gallery of art of the National Government.

In addition he offered to establish an endowment fund which would provide for the salaries of the six principal executive staff officers and for the purchase of works of art, although he expected the building to be maintained by the government. In the letter he made quite plain the standard of excellence which he had set and which he insisted on:

> By reason of the rarity and importance of these works of art, the general character of the collection is such that it will furnish the nucleus of a great national collection and will give our country at once a national gallery that will rank with the other great galleries of the world. In making the collection, I have placed emphasis on quality rather than quantity; and the terms under which the gift would be made are intended solely for the purpose of safe-guarding the collection and insuring efficient management, so that the highest standard of quality will always be maintained in the art to be displayed in the gallery.

President Roosevelt accepted within four days, expressing his delight in the "wonderful offer to the people of the United States." My father's attorney, Donald D. Shepard, then drafted the necessary legislation, and a bill was prepared and introduced in the Congress. The proposed legislation had the approval of the Bureau of the Budget and of the Treasury. It contained all the provisions which my father considered necessary to safeguard the institution in the future. First, the National Gallery, although designated a unit technically of the Smithsonian Institution, was to be governed entirely by its own board of trustees; second, the United States would provide funds for maintenance, administrative expenses and costs of operation; and finally, "no work of art shall be included in the Permanent Collection of the National Gallery of Art unless it be of similar high standard of quality to those in the collection acquired from the donor." Also, "the works of art contained therein shall be exhibited regularly to the general public free of charge."

The bill went through the Senate and the House quickly, and in three months from the date of my father's letter to the President, the National Gallery of Art had come into being with a charter from Congress. The first trustees were elected by June of the same year. The board was small and still is, and we feel that this attribute is one of the most far-sighted and important legacies handed down by my father and his lawyers. The board consisted of nine members, five of them private citizens who were to elect their own successors, and four ex-officio members, the secretary of state, the secretary of the treasury, the secretary of the Smithsonian Institution, and as chairman, the chief justice of the United States. The division of five and four has provided a balance of power; the five private citizens by their majority control the National Gallery of Art even though it is governmentally supported.

My father believed in excellence in men as well as in works of art. He knew that the prestige of a museum depends on the stature of those responsible for its maintenance and growth. This is why he wished the salaries of the top executives to be paid from endowment funds. He did not want the choice of men to be restricted by arbitrary government standards, nor did he like the possibility that the top offices might in the future be distributed as patronage.

The bylaws of the National Gallery of Art provide that the executive officers shall consist of the chairman of the board of trustees, who shall be the chief justice of the United States; also the president, the vice president, director, secretary, treasurer, administrator, chief curator, and assistant director of the National Gallery. An executive committee and two standing committees, of Acquisition and Finance, were also established.

It is a very unusual administrative situation. The three highest staff members, the director, secretary, and administrator have equal executive status. But historically the director has always acted as chief executive for day-to-day functioning. There have been three directors of the Gallery, all men of impeccable taste, great charm, and devotion to their task. John Walker, who had been chief curator, succeeded David Finley, and after his retirement in 1969 Carter Brown became the third director.

The chairmanship has been held by five chief justices of the United States, Charles Evans Hughes, Harlan Fiske Stone, Fred M. Vinson, Earl Warren, and Warren Burger. Each of them had an unflagging interest in the Gallery. It is interesting to note that Chief Justices Hughes, Stone and Warren were all members of the American Philosophical Society. In addition, our first three Smithsonian trustees were also members of this Society; Dr. Charles Abbot, Dr. Alexander Wetmore, and Dr. Leonard Carmichael, the latter your late and very distinguished president, by whom incidentally I had the honor to be inducted into the Society.

The president of the National Gallery, the position I now hold, is however actually the chief executive officer. He is the moderator between the three top full-time professional executives, as well as the interpreter of policies laid down by the trustees. He acts as a liaison officer between the trustees and the staff.

It was tragic that both my father, and the architect he had chosen, John Russell Pope, died within twenty-four hours of each other in August of 1937, a few weeks after the ground-breaking. But although they did not live to see the completed building, they had had, at least, the satisfaction of knowing that the project was well launched.

The National Gallery was dedicated by President Roosevelt on March 17, 1941.

My father's faith in a joint enterprise of the American government and private citizens has been fully vindicated. The monumental building he envisioned stands, no longer with acres of unfilled space, but as a repository of an incredible number of masterpieces. His faith in the generosity of other American collectors was not misplaced.

Even before the National Gallery opened, Samuel H. Kress and the Kress Foundation had made a gift of about four hundred paintings of the Italian Schools. Between 1946 and 1956 the Kress Foundation, spurred by the dedication and enthusiasm of Samuel's brother Rush Kress, spent over twenty-five million dollars on works of art for the National Gallery.

By the time of the opening, Joseph Widener had promised the paintings, sculpture, and decorative arts he and his father had assembled at Lynnewood Hall, and these were installed by 1942. Lessing J. Rosenwald in 1943 first presented a collection of prints and drawings, and this has been augmented each year. In 1962 the Gallery was enriched by the bequest of the Chester Dale Collection of French Impressionists, many of which had long been on loan. In the incredibly short span of twenty-five years the Gallery became one of the leading art museums of the world, attracting nearly two million visitors a year. Another point of interest arises in that of the five largest donations in works of art to the National Gallery—the Andrew Mellon, the Joseph Widener, the Samuel and Rush Kress, the Lessing J. Rosenwald, and the Chester Dale Collections—the first four of these were from individuals either born in Pennsylvania or residing here.

My father's belief in the educational value of a national gallery has also been realized. Within it, guided tours, films, and lectures are offered, all of course without charge. Extension services, comprising films, traveling exhibits, and multimedia programs for schools, reach into some four thousand communities in all fifty states. Books and color reproductions of the highest quality are available to the public at minimum prices. The Gallery also sustains an extensive music program.

Fellowships are offered to encourage young scholars, and the Gallery also sponsors basic scientific research into the problems of conservation.

The success of this experiment has emboldened us to embark on another. There is now being built on an area just east of the present building, between Pennsylvania Avenue and the Mall, a new building which will combine extra exhibition areas with a Center for Advanced Study in the Visual Arts. Nowhere else has such a center been established as the adjunct of a national gallery. The project had long been the cherished ambition of John Walker, born of conversations with the humanist-art historian Bernard Berenson. They both saw Washington as a future center of art scholarship. When John Walker discussed it a few years ago with my sister Ailsa Bruce and myself, we were both enthusiastic about this concept of a great museum joined to a dynamic center of scholarship. We lent our full support, and the project is now being carried out under the watchful eye of our building committee which consists of three trustees—Stoddard M. Stevens, John Hay Whitney, and myself; and Carter Brown, the director.

The new East Building designed by I. M. Pei, its clean contemporary lines complementing the classic beauty of the original building, and constructed of the same Tennessee marble, will offer exhibition space especially suited to the size and boldness of twentieth-century art, as well as more intimate spaces for the exhibition of older schools of art. And, for the Study Center, there will eventually be a library of more than three hundred thousand volumes. Grants from the Kress and Mellon Foundations, a bequest from Chester Dale, and, it is hoped, the provision of further funds from the government, foundations, and private individuals will make it possible for scholars from all over the world to do uninterrupted research without financial anxiety.

In the year of the Nation's Bicentennial, our National Gallery of Art will be just thirty-five years old. Developed in accordance with the dream, but more important, the practical plan of an American private citizen, supported by the federal government, enriched by the donations of many other generous Americans, constantly revitalized by a dynamic educational program, the National Gallery of Art would seem to be approaching its full stature. In the words of Thomas Jefferson some two hundred years ago, it is now,

"in the full tide of successful experiment."

ON ILLUSION AND ALLUSION IN ITALIAN SIXTEENTH-CENTURY PORTRAIT BUSTS

IRVING LAVIN

Professor of Art History, The Institute for Advanced Study

(Read November 14, 1974)

AMONG THE most notable achievements of the Italian Renaissance in art was to have revived the classical tradition of the independent portrait bust.[1] The sculptured portrait did not actually disappear during the Middle Ages, but when it occurred it was included within some physical and conceptual context, notably as part of the decoration of churches and tombs. To say that the Renaissance revived the classical portrait is only a partial truth, however, for in their basic structure Renaissance busts differ profoundly from their ancient predecessors. The typical Roman bust (fig. 1) is rounded at the bottom, hollowed out at the back and set up on a base; its Renaissance counterpart (fig. 2) is cut straight through just above the elbow, it is carved fully in the round, and it has no base. Visually the classical work is a self-contained, abstract form, conceived only from the front and set apart by a base from its support. The Renaissance work is an arbitrarily cut off, incomplete form, conceived in three dimensions and not isolated from the support. From each artist's point of view, the other's creation is grotesque, in the one case because the bust appears like an amputated body, in the other because a human being is made into an inanimate thing. The ancient work is an ideal form, the Renaissance bust is a deliberate fragment, the effect of which is to create an illusion that is entirely new in the history of art. The arbitrary amputation specifically suggests that what is visible is part of a larger whole, that there is more than meets the eye. By focusing on the upper part of the body, but deliberately emphasizing that it is only a fragment, the Renaissance bust evokes the complete individual —that sum total of physical and psychological characteristics to which contemporaries already referred as the "whole man."

This development occurred in Florence around the middle of the fifteenth century. During the second half of the century, measures were taken to heighten the illusion of a complete, living human being. One of these involved the introduction of motion, both implied and actual. In a *Bust of a Lady* attributed to Antonio Rossellino, dating from the 1460's (fig. 3), the arms are separated from the body so that they may function, at least by implication, independently of the torso.[2] Furthermore, a subtle and complicated series of departures from the strict horizontal and vertical axes to which the earlier bust had adhered, is introduced. The head turns slightly to the right and tilts slightly to the left; and the left shoulder is slightly higher than the right. The kind of motion seen here is different from that found in any ancient work. In classical busts the head may look up or down, or turn to one side or the other; but a strict vertical axis is always discernible running through the body, neck, and head, and the shoulders remain on a horizontal line. In other words, the ancient bust has an inviolable, inner structure, for which the

---

[1] This paper is the second of three projected essays on Italian portrait busts from the fifteenth through the seventeenth century. The opening paragraph recapitulates in part the first of the series: I. Lavin, "On the Sources and Meaning of the Renaissance Portrait Bust," *The Art Quarterly* **33** (1970): pp. 207–226. I have anticipated some of the observations made here in various publications: "Five New Youthful Sculptures by Gianlorenzo Bernini and a Revised Chronology of His Early Works," *The Art Bulletin* **50** (1968): pp. 226 f., 239 and n. 107, f.; "Duquesnoy's 'Nano de Créqui' and Two Busts by Francesco Mochi," *ibid.* **52** (1970): pp. 134 ff., 139 ff.; "Bernini's Death," *ibid.* **54** (1972): pp. 176 ff.

Valuable surveys of sixteenth-century bust portraiture will be found in: J. Burckhardt, "Randglossen zur Skulptur der Renaissance," in *Jacob Burckhardt—Gesamtausgabe* (14v., Stuttgart, etc., 1929–1934) **13**: pp. 314 ff.; J. Pope-Hennessy, *Italian High Renaissance and Baroque Sculpture* (2nd ed., London-New York, 1970), pp. 93 ff.; H. Keutner, *Sculpture Renaissance to Rococco* (London, 1969), pp. 27 ff.

[2] The work has also been ascribed to Desiderio da Settignano and Bernardo Rossellino (*cf.* J. Pope-Hennessy, *Italian Renaissance Sculpture* [2nd ed., London-New York, 1971], p. 282).

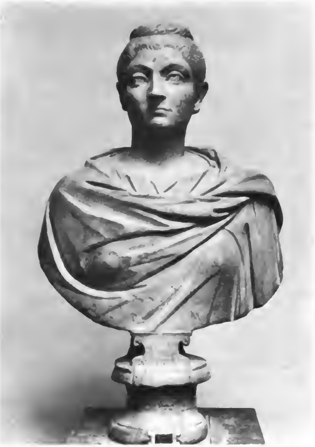

FIG. 1. *Bust of Aurelia Monnina.* Staatliche Museen, Berlin.

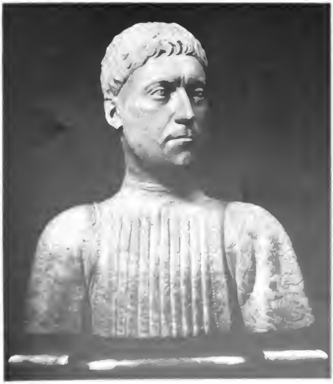

FIG. 2. Mino da Fiesole, *Bust of Piero de' Medici.* Museo Nazionale, Florence (Photo Alinari).

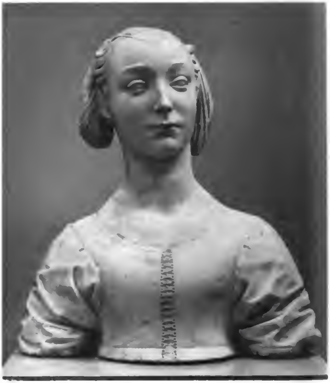

FIG. 3. Attributed to Antonio Rossellino, *Bust of a Lady.* Staatliche Museen, Berlin.

Renaissance artist substitutes a more pervasive mobility.

In the next decade, Andrea del Verrocchio took another bold step. In his *Portrait of a Lady* (fig. 4), he echoed a relatively rare bust type in which both arms are shown in their entirety.[3] But comparison with a Roman work of this kind (fig. 5) reveals differences no less striking than the similarities. The basic structural contrast we noted before is again present; and now also Verrocchio includes a zigzag of motion through the head, neck, chest, and abdomen. The result is a forceful illusion, not only of the whole person, but also of live action; the classical figure seems inhibited by a spinal column in which the vertebrae have fused.

The second contribution of the late fifteenth century is in the realm of expression. To be sure, ancient portraitists explored a wide range of emotions. But there is nothing from classical times to compare with the bust of Beatrice of Aragon by Francesco Laurana (fig. 6), whose inclined head and downcast eyes express a perfect demureness. And nothing from antiquity compares with Verrocchio's bust of Giuliano de'

---

[3] *Cf.* G. Passavant, *Verrocchio* (London-New York, 1969), pp. 33, 180 f.

This One
23RB-FL2-D2DF

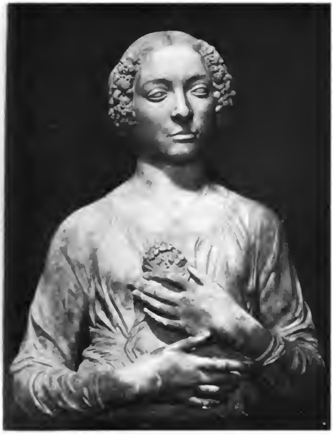

FIG. 4. Andrea del Verrocchio, *Bust of a Lady holding Flowers.* Museo Nazionale, Florence (Photo Alinari).

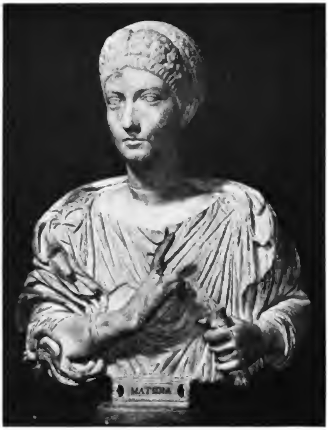

FIG. 5. *Bust of "Matidia."* Uffizi, Florence (Photo Alinari).

Medici (fig. 7), where the proud bearing and the faint smile help to create a sense of genial self-confidence. It should be emphasized that neither of these images would have been possible without the intervening personifications of Christian virtue—the chaste maiden on the one hand, the noble knight on the other. In fact, it might be said that the Renaissance achievement consisted largely in having assimilated the medieval concept of human morality to the classical notion of human individuality.

While this is an important contribution to the portrayal of character, nevertheless there is something curiously discreet and unassuming about these early Renaissance works. The artist was evidently concerned to give an external description of the sitter, of whose inner personality we are made aware implicitly by an abrupt psychological truncation analogous to the treatment of the bust form itself. This relative objectivity has a functional counterpart in the fact that, as far as we can tell from the sources, such portraits served an essentially documentary purpose, as family records. They were made for

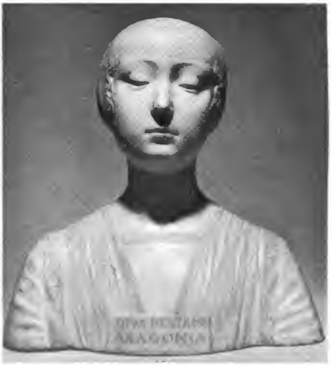

FIG. 6. Francesco Laurana, *Bust of Beatrice of Aragon.* Frick Collection, New York (formerly collection of John D. Rockefeller, Jr.).

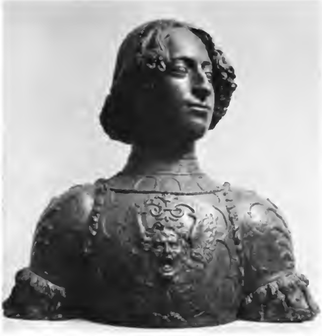

FIG. 7. Andrea del Verrocchio, *Bust of Guiliano de' Medici.* National Gallery, Washington.

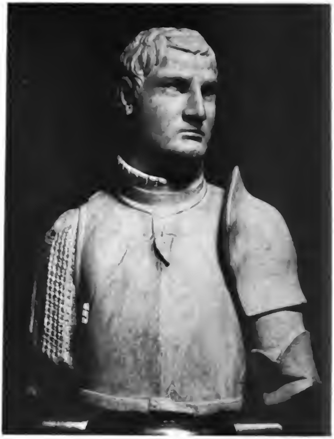

FIG. 8. Francesco da Sangallo, *Bust of Giovanni delle Bande Nere.* Museo Nazionale, Florence (Photo Alinari).

the private home, to whose architecture they were physically attached, over doorways, mantelpieces and the like; and there is no evidence for one of the most conspicuous uses of bust portraits in antiquity, namely, as civic monuments.

In the sixteenth century all this changes. The portrait bust becomes a consciously designed object—no longer simply half a human being, with a consciously conceived expressive purpose—no longer simply a record of the individual. A first critical move in a new direction was taken in the late 1520's in a bust by the Florentine sculptor Francesco da Sangallo (fig. 8), representing Giovanni delle Bande Nere, the father of Cosimo I de' Medici, the first grand duke of Tuscany. It follows the example of Rossellino in the horizontal cut off with the arms separated from the torso, in the turn and tilt of the head, and in the differing level of the shoulders. It follows the example of Verrocchio in that the body is cut off low, at the waistline. The arms continue just below the elbows, and the elbows are shown bent. So far as I can discover, this is the first instance of a bust with severed arms in which the arms are shown in motion. Sangallo thus combined the illusionism of the bust type with the dramatic action of the half-figure type. Another innovation is that the two arms are not symmetrical. While the right arm hangs vertically, the left moves slighly forward, breaking through a heretofore impenetrable plane facing the spectator. In addition, the character of the pose and the defiant expression give the portrait a distinct quality of aggressiveness.

Sangallo also introduced two ingenious devices in designing the amputation of the figure. The torso is cut off in such a way that the bottom line coincides with the lower edge of the armor plate. The amputation is thus dissimulated, so we cannot properly say that the figure is "cut off" at all. On the one hand, the object appears complete and self-contained; on the other hand, nothing prevents us from conjuring up Giovanni delle Bande Nere "in toto." Furthermore, this is the first instance I know in which a severed surface—that of the left arm—is visible from the front.[4] There was only one context in which such visible amputation had occurred before, in actual fragments of ancient statuary. And this is certainly what Sangallo had in mind. The great men of antiquity, were in fact known to the

---

[4] Seen only faintly in our reproduction.

This One
23RB-FL2-D2DF

Renaissance (as indeed they are to us) largely through the broken remains of honorific statues, and the visibly severed arm suggests not only that the bust is part of a larger figure but that Giovanni delle Bande Nere was like the venerable heroes of classical times.[5]

The aggressive quality of the pose and expression, the element of self-containment in the design, and the explicit reference to antiquity—these features are new and they coalesce in a new conception of the portrait bust, which is no longer simply a record, but a mode of exaltation of the individual as well. When we recall that Giovanni delle Bande Nere played a key role in the political transformation of Florence from a republic into the grand duchy that became the model for the system of absolute monarchies of the seventeenth century, the sense of this exaltation becomes clear.

For the early Christians the portrait bust became a symbol of pagan idolatry,[6] a stigma so potent that the familiar classical bust type—rounded at the bottom, hollowed at the back and raised on a base—was not fully revived on a monumental scale until the second quarter of the sixteenth century, and even so in a work that cannot really be called a portrait. About 1539–1540 Michelangelo made a bust of Brutus, which is the first monumental marble sculpture of this class since antiquity (fig. 9). Michelangelo adopted not only the form, but also the pose, expression and costume of a well-known portrait type of the Emperor Caracalla (fig. 10), assimilating to it the depictions of Brutus on Roman gems and coins.[7]

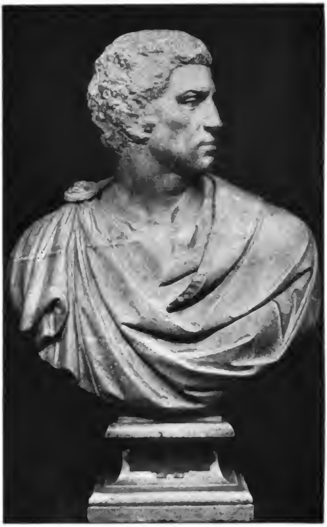

FIG. 9. Michelangelo, *Bust of Brutus.* Museo Nazionale, Florence (Photo Anderson).

---

[5] An interesting passage in this context, brought to my attention by Phillip Foster, occurs in Poggio Bracciolini's dialogue *De Nobilitate* (*ca.* 1440), where the ancient custom of decorating the home with ancestral portraits is ironically connected with the modern vogue for collecting fragments of classical statuary (*cf.* G. Holmes. *The Florentine Enlightenment 1400–50* [New York, 1969], p. 228). In North Italy at this period, "incomplete" figure sculptures began to be made deliberately in imitation of ancient fragments (L. Planiscig, *Venezianische Bildhauer der Renaissance* [Vienna, 1921], pp. 335 f.; H. Ladendorf, *Antikenstudium und Antikenkopie* [Berlin, 1953; *Abhandlungen der sächsischen Akademie der Wissenschaften zu Leipzig.* Philologisch-historische klasse, Band 46, Heft 2], p. 36; M. Perry, "A Greek Bronze in Renaissance Venice," *Burlington Magazine* **117** [1975]: pp. 204 ff.); for a possible influence of such fragments on bust design, see now S. Wilk, "Tullio Lombardo's 'Double Portrait' Reliefs," *Marsyas* 16 (1972–1973; publ. 1974): p. 77.

[6] See E. Becker, "Protest gegen den Kaiserkult und Verherrlichung des Sieges am Pons Milvius in der christlichen Kunst der konstantinischen Zeit," in F. J. Dölger, ed., *Konstantin der Grosse und seine Zeit* (Freiburg i. B., 1913; *Römische Quartalschrift* 19. Supplementheft), pp. 155–190.

[7] *Cf.* C. de Tolnay, *The Tomb of Julius II* (Princeton, 1954), pp. 76 ff., 131 ff.; for depictions of Brutus on gems, see now M.-L. Vollenweider, *Die Porträtgemmen der römischen Republik* (Mainz, 1974), pp. 139 ff. Further to the background in D. J. Gordon, "Giannotti, Michelangelo and the Cult of Brutus," in D. J. Gordon, ed., *Fritz Saxl 1890–1948. A Volume of Memorial Essays from His Friends in England* (London, 1957), pp. 281–296, and N. Rubinstein, "Political Ideas in Sienese Art: The Frescoes by Ambrogio Lorenzetti and Taddeo di Bartolo in the Palazzo Pubblico," *Journal of the Warburg and Courtauld Institutes* **21** (1958): pp. 195, 198, 207.

For the antecedents to Michelangelo's innovation, see W. von Bode, "Die Ausbildung des Sockels bei den Busten der italienischen Renaissance," *Amtliche Berichte aus den preuszischen Kunstsammlungen* **40** (1918–1919): cols. 112 ff., to which should be added the actual

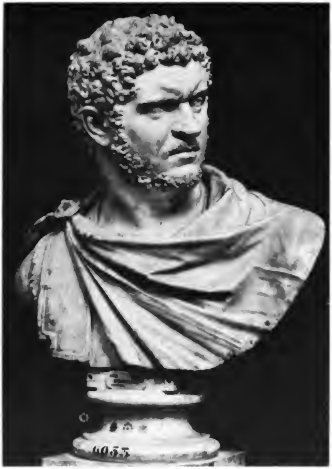

FIG. 10. *Bust of Caracalla.* Museo Nazionale, Naples (Photo Anderson).

Apart from its form and expressive content, two points concerning the bust should be noted. One is that, although the work does not represent a contemporary personage, the time and circumstances of its execution show that it did have a contemporary political significance, reflecting the republican sentiment in Florence in favor of the assassination of a potentially tyrannical member of the Medici family. Hence, while the bust depicts the antagonist of Caesar, it also embodies an abstract idea, that of the noble tyrannicide. From the very moment of its revival, therefore, the classical bust type carried a heavy burden of meaning. It was a kind of visual metaphor, serving to raise the person represented to a higher plane of existence. The second point concerning the *Brutus* is that it moves in a way no earlier bust moved. Much of its powerful effect depends upon the fact that the left shoulder is thrust strongly forward with respect to the right (not just a movement of the arm, as in the Sangallo bust). In previous portraits, including ancient ones, the shoulders adhered to a frontal vertical plane. The movement gives the Brutus bust a strong suggestion of life and vitality underlying the abstract form and content, a counterpart to the "living" relevance of its subject.

Following Michelangelo's lead, the final act in the creation of a new portrait form took place in Florence a few years later, under very different circumstances. The first busts of the ideal type representing a contemporary personage were made toward the middle of the sixteenth century by two arch rivals who were vying for the

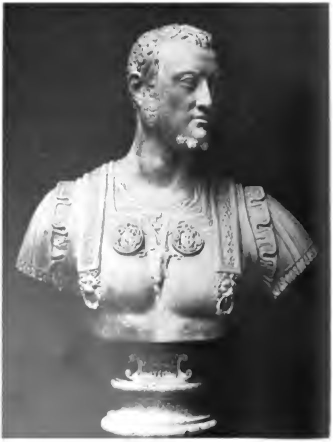

FIG. 11. Baccio Bandinelli, ***Bust of Cosimo I de' Medici.*** Museo Nazionale, Florence (Photo Alinari).

---

copies and restorations of ancient Roman busts made in North Italy (H. J. Hermann, "Pier Jacopo Alari-Bonacolsi, genannt Antico," *Jahrbuch der kunsthistorischen Sammlungen des allerhöchsten Kaiserhauses,* **28** [1909–1910]: pp. 276 ff.; *cf.* Keutner, *Sculpture* [cited in n. 1 above], p. 28); also a bust of Pius II in the Vatican by Paolo Romano, which was placed above a doorway, however, and I suspect had no base (*cf.* R. Olitzky Rubinstein in F. A. Gragg, trans., and L. C. Gabel, ed., *Memoirs of a Renaissance Pope. The Commentaries of Pius II. An Abridgement* [New York, 1959], note on fig. 1, p. 11; A. M. Corbo, "L'attività di Paolo di Mariano a Roma," *Commentari* **17** [1966]: pp. 200, 213, Doc. 74).

This One
23RB-FL2-D2DF

favor of the despotic ruler of Florence, Cosimo I de' Medici. In his marble bust of Cosimo of about 1544 (fig. 11), Baccio Bandinelli perpetrated what would heretofore have been considered virtually an act of idolatry: an independent, honorific bust of a living individual in the mode of pagan antiquity. Cosimo is treated literally as though he were a Roman emperor, in the form of the bust itself, in the armored cuirass he wears, and in its adulatory function. The conception of the portrait bust as an explicit political statement initiated by Michelangelo is here turned completely about, so that from a symbol of republicanism it becomes the visual herald of modern absolutism.

The underlying modernity of the bust is evident visually, as well. In following classical precedent, Bandinelli selected the one notable type from antiquity which suggests that it is part of a larger whole. This occurs in busts of Antinous the favorite of the Emperor Hadrian, who caused him to be divinized and worshiped as a god (fig. 12). They are smooth and regular in outline, but asymmetrical, with the head turned to the side and slightly downward and one arm raised. The design deliberately hints that the bust is cut from a whole statue, and in fact the pose is derived from full-length statues of gods and heroes. The purpose clearly was to assimilate the portrait of Antinous, an ordinary mortal, to the idea of Antinous as a deity.

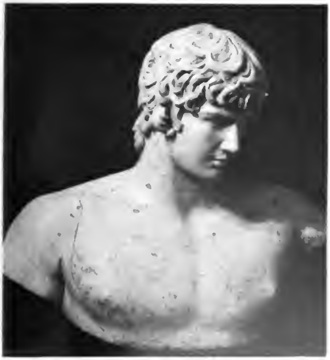
FIG. 12. *Bust of Antinous.* Museo del Prado, Madrid (Photo MAS).

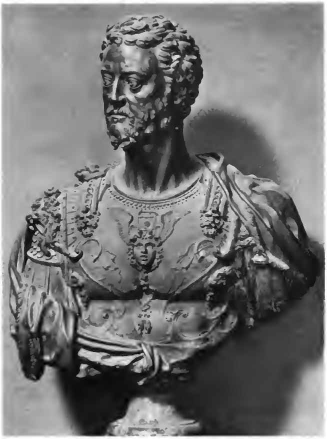
FIG. 13. Benvenuto Cellini, *Bust of Cosimo I de' Medici,* Museo Nazionale, Florence (Photo Alinari).

In suggesting that the bust is part of a statue Bandinelli shows his indebtedness to Sangallo, but he takes the significant step of referring explicitly to the outstanding classical prototype that accomplished the same thing. Bandinelli's bust differs from the ancient model, however, in two essential ways. The head and neck are tilted slightly off the vertical axis, the right shoulder is slightly higher than the left, and the raised left arm is cut free of the body. Once again, the figure has the independence and continuity of movement of a living human being. The second difference is in the treatment of the arms, where Bandinelli adopts a variation of the principle of dissimulation introduced by Sangallo. The cut of the arms corresponds to the ends of the epaulettes of the cuirass.[8] Hence the arms are not actually amputated, and their forceful action is continued in the mind's eye. Bandinelli's bust involves a

---

[8] Precedents for the device may be seen in Donatello's reliquary bust of St. Rossore (see n. 10 below), and in Verrocchio's *Giuliano de' Medici* (fig. 7).

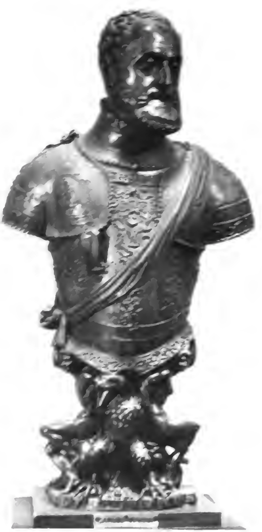

FIG. 14. *Leone Leoni, Bust of Charles V.* Museo del Prado, Madrid (Photo MAS).

two-fold visual pun. Insofar as it appears cut off it suggests part of a larger whole, namely a complete statue. Insofar as it is dissimulated it also suggests part of a larger whole, a complete human being. In the end, the bust can only be described as a new art form, at once independent and self-contained, yet through a combination of illusion and allusion, infinitely evocative.

Bandinelli's great antagonist, Benvenuto Cellini also did a bust of Cosimo at this time, a colossal bronze (fig. 13). The scale itself is a measure of the element of personal aggrandizement.[9] The classical convention is referred to in the form of the bust, but again it is modernized in pose and design. Now for the first time both arms move, one forward, the other back, so that a veritable counterpoint is introduced, giving the figure a spatial content and a continuity of action it had never had before. Furthermore, Cellini comes to grips in a new way with the problem posed by the classical bust form, with its raised, curved outline. Bandinelli, following Sangallo, had dissimulated the edges by making them coincide with the edge of a garment or of a cut out statue. For the left arm of his figure Cellini adopts the same device, but in addition he throws a cape over the shoulders which is draped around the right half of the figure in a special way.[10] It covers the lower edge and is arranged so that it appears folded, rather than cut off. The drapery acts as a kind of proscenium, hiding the severed edge, yet self-contained and therefore not cut off itself. As a result, only the short edge at the lower right remains to remind us that this is not Cosimo himself, but a bust of Cosimo—an essential element if the work is to carry visually its honorific message.

These Florentine busts of the mid-sixteenth century set the pattern for the entire future development of the genre. In the course of the century three major branches grew from this central Italian trunk. The Tuscan tradition was raised to new heights, particularly at the hands of Leone Leoni, whose portraits of the Hapsburg family actually brought the bust into the imperial service. In his bronze *Charles V* (1553–1555; fig. 14) the breast and shoulder plates of a suit of armor completely dissimulate the amputation of torso and arms; and this empty shell, which the mind fills with the spirit of the man, does not rest on an abstract base, but is carried aloft in apotheosis by the imperial eagle and two allegorical figures.

Another mode developed in Venice. In the portraits of Alessandro Vittoria (*cf.* fig. 15), drapery plays a role equivalent to the armor in Leoni's. It falls in ample folds that hide the body beneath, and it is cut in irregular shapes so as to create the effect of an apron or screen before a void, which the imagination ineluctably fills up. The torsos, moreover, tend to be vastly inflated, so that the figures appear larger than life—regardless of their scale. Finally, they never have the strident tone and allegorical paraphernalia of the Medicean works. Rather, Vittoria's busts display a pompous gravity and lofty concern, expressive of the ideals of Venetian republicanism.

---

[9] 110 cm. high, excluding base; Verrocchio's *Giuliano de' Medici*, 61 cm.; Michelangelo's *Brutus*, 74 cm. excluding base.

[10] Cellini is here also evidently indebted to Donatello's *St. Rossore*; *cf.* Lavin, "Sources and Meaning" (cited in n. 1 above), p. 212.

The third major off-shoot was in Rome, where a very different formula emerged. The tone was set by Guglielmo della Porta in a portrait of Pope Paul III (1546–1547; fig. 16). The drapery again submerges the body, but instead of loose and ample folds, it forms a sort of cocoon around the figure. The body has none of the movement of the Florentine works. The outline is closed and regular and the eyes look out from the heavy, patriarchal head with an almost accusative air. The robe is decorated with reliefs explaining in symbolic terms the secular and religious mission of the pope. Paul III, it will be remembered, initiated a period of aggressive self-scrutiny in the church that blossomed into the great movement of spiritual elevation known as the Counter-Reformation.

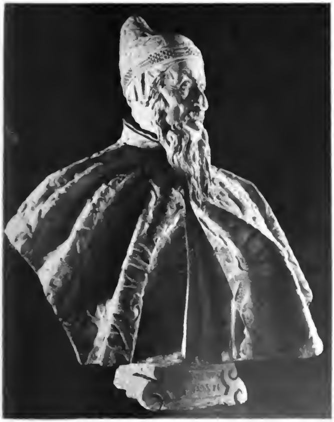

FIG. 15. Alessandro Vittoria, *Bust of Doge Nicolò da Ponte.* Seminario, Venice (Photo Böhm).

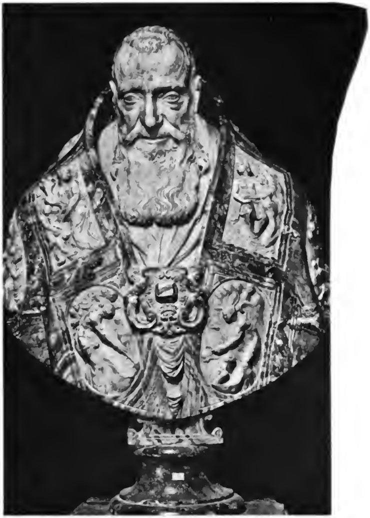

FIG. 16. Guglielmo della Porta, *Bust of Pope Paul III.* Museo Nazionale, Naples (Photo Anderson).

These three great expressive conventions—modes of characterization, to be more precise—the Florentine imperial, the Venetian republican, and that of the Roman Counter-Reformation, constitute the main achievement of Italy in the sixteenth century in this domain. They fuse three essential elements: the illusion of a living presence in the bust, the allusion to classical antiquity, and the elevation of the individual represented to an ideal. A symptom of their differences from the Renaissance type is the consciousness with which the fusion was achieved. We have comments by both Bandinelli and Cellini in letters to Cosimo de' Medici, which show that the artists were fully aware of what they were about.[11] Cellini speaks of his portrait as being "in accord with the high manner of the ancients," and "having the bold movement of life." Bandinelli says of another of his busts of the Duke that it is "as if to see Octavian or Pompey the Great extend his arm to pacify the people." Even more striking is a further passage in which he says that if the duke should prefer a whole statue, arms and legs could easily be added—a frivolity perhaps, yet clearly indicative of the implied wholeness with which he conceived the work. Above all, busts of this period seem far more imposing—"surpassing everything ideal and pathetic" was Jacob Burckhardt's phrase for them [12]—than their Renaissance predecessors, both visually and psychologically. Here, too, the effect had a functional counterpart; they might be displayed on pedestals of their own and, no longer confined to the sitter's home, they acquired a new "public" significance.[13] In sum, they are pieces of monumental rhetoric, and as such they confront us with a remarkable paradox. We tend to think of the portrayal of human nature as an analytical process of stripping away convention. Instead, the development of the portrait bust since the Renaissance suggests an opposite view—that character and convention are inseparable, the one expressed through the other. In the process we have traced, the individual and the heroic emerged together as the compound product of one creative synthesis.[14]

---

[11] *Cf.* D. Heikamp, "In margine alla 'Vita di Baccio Bandinelli' del Vasari," *Paragone* (1966), No. 191: pp. 57 f. On Bandinelli's and Cellini's busts of Cosimo, see further the illuminating study by K. W. Forster, "Metaphors of Rule. Political Ideology and History in the Portraits of Cosimi I de' Medici," *Mitteilungen des kunsthistorischen Institutes in Florenz* **15** [1971]: pp. 76 ff.

---

[12] *Gesamtausgabe* (cited in n. 1 above) **13**: p. 314.

[13] The revival in the sixteenth century of the full-length pedestal for portrait busts was noted by A. Schiaparelli, *La casa fiorentina e i suoi arredi nei secoli XIV e XV* (Florence, 1908), p. 194. Surveys of the many Medicean busts which begin now to populate the façades of public buildings and the houses of the rulers' friends in Florence will be found in *L'illustratore fiorentino* **6** (1909): pp. 5–9, and K. Langedijk, *De Portretten van de Medici tot omstreeks 1600* (Diss., Amsterdam, 1968), pp. 66, 91, 99 f. A Florentine law of 1571 prohibited the removal or defacement of such works displayed on public and private buildings (*cf.* D. Heikamp, "Die Bildwerke des Clemente Bandinelli," *Mitteilungen des kunsthistorischen Institutes in Florenz* **9** [1959–1960]: pp. 130 f.; the reference is evidently to the *Legge contra chi rimovesse, o violasse armi inscritioni, o memorie esistenti apparentemente nelli edifitij cosi publici, come privati . . .* , Florence, May 30, 1571 [copy in Biblioteca Nazionale Centrale, Florence], cited by L. Manzoni, *Bibliografia statutaria e storia italiana* [3 v., Bologna, 1876–1893] **1**, **2**: p. 200). As early as 1514 in Mantua, busts of the quattrocento type representing illustrious Mantuans were privately commissioned to decorate an ancient city gate (cited by H. Keller, *Das Nachleben des antiken Bildnisses von der Karolingerzeit bis zur Gegenwart* [Freiburg i. B., 1970], p. 97, n. 3).

[14] For a remarkable study of the development of character portrayal in Florentine historiography and rhetoric of the sixteenth century, see H. Gmelin, *Personendarstellung bei den florentinischen Geschichtschreibern der Renaissance* (Leipzig, 1927, a reference for which I am indebted to Professor Felix Gilbert). Related also are the development of biographical theory (e.g., G. A. Viperano, *De Scribenda virorum illustrium vitis* [Perugia, 1570]; *cf.* B. Weinberg, *A History of Literary Criticism in the Italian Renaissance* [Chicago, 2 v., 1961] **1**: pp. 43, 297 f.), and a theory of portraiture in art (M. Jenkins, *The State Portrait. Its Origin and Evolution* [n.p., 1947; Monographs on Archaeology and Fine Arts sponsored by the Archaeological Institute of America and the College Art Association of America, vol. III], pp. 34 ff.; *cf.* also G. A. Paleotti, *Discorso intorno alle imagini sacre e profane* [Bologna, 1582], in P. Barocchi, *Trattati dell'arte del cinquecento* [3v., Bari, 1960–1962] **2**: pp. 30 ff.). A relationship between portraiture and physiognomical theory at this period has been suggested by P. Meller, "Physiognomical Theory in Renaissance Heroic Portraits," in *Acts of the Twentieth International Congress of the History of Art*, New York, 1961 (4 v., Princeton, 1963) **2**: pp. 53–69.

FERTILITY DIFFERENTIALS BETWEEN LESS DEVELOPED AND DEVELOPED REGIONS: COMPONENTS AND IMPLICATIONS

SIMON KUZNETS

Professor Emeritus of Economics, Harvard University

1. INTRODUCTION

THE CRUDE birth rates in the economically less developed countries have been over twice those in the developed countries in the recent decades. Such differentials imply differences in age patterns of birth rates through the life cycles of mothers and fathers; in age at time of marriage, and between husbands and wives in later life; in birth parities; and in the size of households, in so far as they reflect the number of children in them. In turn, all these demographic differences have economic and social connotations, and these provide an indispensable framework for interpreting the persistence of high birth rates in the less developed regions.

The paper presents a brief summary of the easily available recent cross-section data on the demographic components in the international fertility differentials, with emphasis on the comparison of less developed (LDCs) and more developed (DCs) regions among the market economies. This summary, and the accompanying analytical comments, may be familiar to specialists in demography. But the interrelations of these demographic aspects, and their possible connotations, are less familiar to economists; and the recent additions of data on less developed regions, sparsely covered, if at all, in earlier years (most of Africa and much of Asia) make it worth while to assemble the summary measures. No effort was made to go back to the original censuses or monographic studies; and I have relied primarily on the international compilations and special papers of the United Nations. The aim was a broad survey, on the assumption that guidance for a more intensive exploration would be provided by such an approach.

The discussion begins with a review of the age specific birth rates for women in the successive age classes within the childbearing span; these, together with number of women in these age classes, absolute and in relation to total population, are used to derive the crude birth rates. We can then establish the contribution of each age class of women to the total crude birth rate of a region. The next section reviews marriage proportions among women, derives age specific marital fertility ratios, and measures the contribution to fertility differences between the LDCs and DCs of the differences in marriage proportions and in intra-marital fertility. The third section compares the distributions of births by age of mother, and an approximation to the distributions of births by age of father, for the LDCs and the DCs. The fourth section summarizes births by birth order or parity, indicating the greater weight of high parity births in the total fertility of the LDCs; and establishes the association between the incidence of births to parents at more advanced ages and the contribution of high parity births to higher fertility. The fifth, and last, section devoted to statistical evidence deals with the distribution of population among households of different size, stressing the association between higher fertility and the larger average size of household, or higher proportions of larger households, in the LDCs than in the DCs. In the concluding section an attempt is made to indicate what the findings contribute to the explanation of persisting high birth rates in the LDCs.

2. AGE SPECIFIC BIRTH RATES, WOMEN

We begin with a summary of the birth rates of women in the five-year age classes in the childbearing span from 15 through 49 years of age (table 1). Since these are *annual* rates, an entry of 124 in line 1, column 2 means that there were 124 births per year for every 1,000 women 15–49 years old, or 620 births per 1,000 women over the five years covered by that age class.

The regions distinguished are those of most interest in the study of economic growth and levels of living. A more detailed breakdown would, of course, be desirable, but the data and resources are not available. In general, the regional rates are unweighted averages of those for individual countries, the presumption being

PROCEEDINGS OF THE AMERICAN PHILOSOPHICAL SOCIETY, VOL. 119, NO. 5, OCTOBER 1975

TABLE 1

Annual Births per 1,000 Women, by Age of Women, Less Developed and Developed Regions, Early or Middle 1960's

	Number of Countries (1)	Age of Women							Total Fertility (9)
		15–19 (2)	20–24 (3)	25–29 (4)	30–34 (5)	35–39 (6)	40–44 (7)	45–49 (8)	
A. Market Economies									
I. Less Developed Regions									
1. East & Southeast Asia	9	124	275	280	223	154	64	22	5,710
1*a*. India–Pakistan	2	158	277	266	209	140	56	24	5,650
1*b*. Other countries	7	62	268	305	248	179	78	19	5,795
1*c*. Hong Kong & Singapore	2	48	247	315	237	148	58	8	5,305
2. Middle East	9	113	305	352	290	199	82	17	6,280
3. Sub-Saharan Africa	16	183	295	268	219	153	77	32	6,135
4. Latin America	16	121	296	308	243	181	74	22	6,225
5. Total, LDCs (lines 1–4, weighted)		131	283	289	231	161	69	23	5,935
II. Developed Regions									
6. Europe	13	32	152	168	106	54	17	1	2,650
7. Overseas offshoots	4	59	221	208	125	64	19	2	3,490
8. Japan	1	4	109	192	83	22	4	0	2,070
9. Total, DCs (lines 6–8, weighted)		38	171	187	110	53	16	1	2,880
III. Other Market Economies									
10. Europe	4	18	121	186	147	93	36	4	3,025
11. Latin America	3	76	203	185	125	78	31	6	3,520
B. European Communist Economies									
12. Developed	3	49	177	135	78	38	12	2	2,455
13. Less developed	5	52	173	128	69	34	12	2	2,350
14. Albania	1	56	275	305	256	189	117	58	6,280

Notes:

Entries in columns 2–8 for all countries, except the four listed below, are from United Nations, *Interim Report on Conditions and Trends of Fertility in the World, 1960–1965*, Population Studies, no. 52 (New York, 1972), various Annex tables. We omitted countries with population below a million. In general, we took means of the values for 1960 and 1965; or the values for one of the two years, if its base was more reliable or its coverage more comprehensive. For the Congo (Leopoldville), 1955–1957; Guinea, 1955; India, 1958–1959; and the Philippines, 1950–1955, data are from United Nations, *Population Bulletin no. 7, 1963* (New York, 1965), table 7.1, pp. 102–103.

Unless otherwise indicated, entries for regions that include more than one country are unweighted arithmetic means of the values for the several countries. The weights, when used, are population numbers for 1960 given in United Nations, *Population Estimates by Regions and Countries, 1950–1960*, Working paper ESA/P/WP31, May, 1970.

Line 1: Weighted mean of lines 1*a* and 1*b*, the relative population weights (in the total comprising other East Asia, excluding North Korea; Middle South Asia, and Southeast Asia excluding North Vietnam) being 0.645 for line 1*a* and 0.355 for line 1*b*. Line 1*c* is excluded.

Line 1a: Weighted mean with weights of 0.81 for India and 0.19 for Pakistan.

Line 1b: Includes South Korea, Taiwan, West Malaysia, Thailand, Cambodia, Ceylon, and the Philippines.

Line 2: Represents Southwest Asia and North Africa, and includes Turkey, Iraq, Jordan, Syria, United Arab Republic, Sudan, Libya, Tunisia, and Algeria.

Line 3: Includes Cameroon, Central African Republic, Chad, Congo, Dahomey, Ghana, Guinea, Ivory Coast, Madagascar, Kenya, Mali, Niger, Senegal, Togo, Uganda, and Upper Volta.

Line 4: Includes Mexico, Brazil, Colombia, Peru, Venezuela, Ecuador, Guatemala, Honduras, Nicaragua, Dominican Republic, Chile, Paraguay, El Salvador, Costa Rica, Jamaica, and Panama.

that each country, large or small, represents an item of significant evidence. But we omitted countries with a population of less than a million, because of the possibility of erratic results. Moreover, when large countries showed distinctive patterns (as was the case with India and Pakistan, compared to other countries in East and Southeast Asia) we took weighted averages for them separately. Finally, we weighted regional rates by population in combining them into aggregates for all LDCs and DCs.

Total fertility is the sum of births over the childbearing span to 1,000 women, representative of the population covered in a specific area. Thus, the entry in line 1, column 9, indicates that 1,000 women with the fertility patterns of women in East Southeast Asia in the early 1960's bore 5,710 children through their childbearing span, an average of 5.71 births per woman.

Several findings are suggested. To begin with total fertility, birth rates per 1,000 women of childbearing ages were, among the market economies, over twice as high in the LDCs as in the DCs. The few European and Latin American economies that did not clearly fit into either of these two large groups showed fairly low total fertility, closer to that for the DCs than to that for the LDCs. The distinctive, and less expected, finding was that among the European Communist economies, excluding Albania, fertility was low, even relative to the developed countries of Europe; and just as low, or slightly lower, among the less developed Communist economies than among the more developed. Obviously, some aspects of the social and economic structure of European Communist economies restrict fertility sharply and effectively.

Second, and more relevant to our specific topic, is the difference between the LDCs and DCs in the pattern of their age specific birth rates over the childbearing span. For the LDCs the rates are fairly high not only during the prime ages, from 20 through 29, and the next higher class from 30 through 34, but also during the younger and older ages. Thus, if we view an age specific birth rate of 100 (500 births in a five-year interval) as an index of substantial childbearing, we find that such engagement extends over five age classes, or 25 years, in the LDCs, and only over three age classes, or 15 years in the DCs (lines 5 and 9).

Indeed, one could argue that it would be difficult, if not impossible, to attain a total fertility as high as that found for the LDCs, i.e. between 5,700 and 6,800, if births were limited to women 20 through 34 years old. With fecundity proportions rising rapidly from about a third of all women aged 17 to a peak of 93 per cent at age 22, and then declining slowly beginning at age 23 and through the early 30's, the average proportions of fecund women are 39 per cent for age 15–19, 92 per cent for age 20–24, 90 per cent for age 25–29, and 85 per cent for age 30–34.[1] Given these levels, and observing the record for individual countries, we find that a reasonably high age specific rate would average 350 for the two prime fecundity classes, i.e. 20–24 and 25–29, and about 300 for the 30–34 class—thus yielding total fertility of 5,000, without any births to younger and older women. But this would fall short of the total fertility shown in lines 1–5 by between 12 and 26 per cent; yet the assumed total fertility, given an average married proportion below 90 per cent (see below) would mean, for the three age classes, an average of almost six births per married woman over the fifteen years. It is unrealistic to assume that an average of one birth every two and a half years, over a span of fifteen years, can be maintained for every married woman in the population. The cumulative total for the three age classes would fall short of the 5,000 total fertility level, and the difference, like that between 5,000 and 6,000 or more, would have to be made up by fairly high birth rates for younger and older women.

---

[1] See Frank Lorimer and others, *Culture and Human Fertility* (Paris, UNESCO, 1954), pp. 52-53; quoted in United Nations, *Population Bulletin, no. 7, 1963* (New York, 1965), p. 101. Section VII of this *Bulletin*, pp. 101–121, has extensive discussion of age patterns of fertility.

Fecundity is the physiological capacity of woman for procreation, and is characterized by a rather narrowly defined span with greatly varying levels within the span.

Line 5: Weighted averages of lines 1–4. The weights for line 1 as indicated; for line 2—populations of Southwest Asia and North Africa; for line 3—the sum of populations of West, East, and Central Africa; for line 4—population of Latin America, omitting the Temperate Zone—work out to 63 for line 1, 9 for line 2, and 14 each for lines 3 and 4.

Line 6: Includes Belgium, Denmark, Norway, Sweden, Finland, Netherlands, France, Germany (Federal Republic), Switzerland, Austria, Italy, England and Wales, and Scotland.

Line 7: Includes Canada, United States, Australia, and New Zealand.

Line 9: Weighted averages of lines 6–8. The weights—the population totals for Northern and Western Europe, plus Italy (omitting the rest of Southern Europe); and for the other regions—work out to 46 for Europe, 38 for overseas offshoots, and 16 for Japan.

Line 10: Includes Ireland, Greece, Spain, and Portugal.

Line 11: Includes Argentina, Uruguay, and Puerto Rico.

Line 12: Includes U.S.S.R., Czechoslovakia, and East Germany.

Line 13: Includes Poland, Hungary, Romania, Yugoslavia, and Bulgaria. Excludes Albania shown separately in line 14.

Column 9: Sum of rates for seven age classes, multiplied by five (to allow for the number of years in each class interval). Each entry shows the total number of births over the childbearing span to 1,000 women, aged 15–49, representative of the population reflected in the cross section.

Third, if there is an element of necessity about the extended pattern of age specific birth rates in the LDCs compared with the more concentrated pattern in the DCs, there is still an element of variance or choice. In some countries the additional contribution to high total fertility occurs largely among women under 20; in others it occurs among those 35 or older. Thus in India and Pakistan (line 1*a*), and Sub-Saharan Africa (line 3), the rate in the 15–19 class is over 150 per thousand, whereas in the other countries in East Southeast Asia (line 1*b*), and to a lesser extent in the Middle East (line 2), the rate for the 15–19 class is relatively low, 62 or 113. And, as one would expect, when the time pattern is extended toward early ages, the specific rates at the later ages tend to be lower than when the time pattern is not extended back of age 20. Thus, for India and Pakistan, and Sub-Saharan Africa, the rates for age 30–34 are 209 and 219 respectively, compared with the much higher rates for other countries in East Southeast Asia and in the Middle East (248 and 290 respectively). When the birth rates are fairly high in the 15–19 class, the rate tends to be at the peak in the 20–24 class, declining somewhat in the 25–29 class; whereas in regions with relatively low rates at the early ages, the peak is reached in the 25–29 class. The differences indicated between the India-Pakistan and Sub-Saharan regions, on the one hand, and the Middle East and East Southeast Asia, reflect different institutional conditions governing age of marriage, particularly of women, and suggest the diversity of age patterns that can be associated with a high level of total fertility.[2]

Finally, it follows that the excess of fertility in the LDCs over that in the DCs may be accounted for by higher birth rates of the former, partly in the young ages (below 20), partly in the prime ages (20–34), and partly in the older ages (35 and over). However, we are interested in a comparison not of total fertility, but of crude birth rates—for it is crude birth rates, in combination with crude death rates, that yield the rate of natural increase, or natural growth of population—with its effects on economic growth and structure. We must, therefore, shift now to the links between total fertility and crude birth rates: the relative size of each age class of women of childbearing ages, and the proportion of *all* women of childbearing ages to total population. Table 2 summarizes the data on both links, shows the resultant aggregate crude birth rates, and measures the contribution to the differences in the crude birth rates made by women in each age class within the childbearing span.

---

[2] High total fertility, even higher than that for the less developed countries today, was shown in the past in some of the currently more developed countries—but always with a low birth rate for the younger age class. Thus, in European Russia in 1897, total fertility was as high as 7,060 but the rate for the 15–19 class was only 30; similar rates for Bulgaria for 1901–1905 were 6,570 and 23; for Serbia and Croatia-Slavonia combined in 1910, 5,595 and 44 (see Robert R. Kuczynski, *The Balance of Births and Deaths* **2**: various tables, The Institute of Economics of the Brookings Institution, New York, 1931). In the successor states—USSR, Bulgaria, and Yugoslavia—total fertility rates for the mid-1960's, according to United Nations sources, ranged from 2,075 for Bulgaria to 2,695 for Yugoslavia.

If we group the 52 countries covered in lines 1–5 of table 1, i.e. all the less developed, *including* Hong Kong and Singapore, in descending order of the birth rate for the younger age group, 15–19, and strike group averages, the following associations are revealed:

Averages of Age Specific Birth Rates, Countries Grouped in Declining Order of the Rate for the 15–19 Class

Groups (number of countries in parentheses)	15–19 (1)	20–24 (2)	25–29 (3)	Changes (1–2) (4)	(2–3) (5)	Total Fertility (6)
1. Top (6)	239	309	289	70	−20	6,665
2. II (6)	173	305	285	132	−20	6,455
3. III (7)	147	310	294	163	−16	6,155
4. IV (7)	136	288	298	152	10	6,030
5. V (7)	124	308	339	184	31	6,745
6. VI (7)	105	299	322	194	23	6,435
7. VII (6)	75	265	291	190	26	5,885
8. VIII (6)	45	244	299	191	55	5,250

As the rate for the youngest class declines, the change in the rate from the 20–24 to the 25–29 class shifts from a minus to a plus, thus indicating the movement of the peak toward later ages. Even more interesting is the fact that through the sixth of the eight groups, total fertility shows no decline. This is because the decline of more than 100 points in the age specific rate for the 15–19 class is offset by the rise in the rates at the later ages.

Panel A reveals that the relative magnitude of the age classes among women in the less developed areas declines significantly as we move from the youngest group, 15–19 years of age, to the oldest, 45–49. A simple geometric mean of the relatives of the two youngest and the two oldest classes, for the LDCs as a whole (line 5) yields a rate of rise from the older to the younger groups of 3.3 percent per year (we prefer to think of it as a rise toward the younger, rather than a decline toward the older, age groups). This result is not surprising: the younger groups are larger than the older because they are members of a larger population, i.e. are survivors of a birth cohort that, with population growth, was larger than the one born earlier and now represented by the older classes. Furthermore, the older groups would have been smaller, even with the same initial birth cohort, because of the longer cumulation of attrition by death. And it is not difficult to derive the 3.3 per cent rate as a combination of a past population growth rate of about 2.5 per cent (within some range) and age specific death rates over the span from 15–19 to 45–49 of say 6 to 8 per 1,000 per year.

Since both past population growth rates, and the death rates within the relevant span, were much lower for the DCs than for the LDCs, one would expect a correspondingly lower rate of rise for the former in the numbers, moving from the older to the younger classes among women. And indeed the rate derived from the geometric means of the two classes at each end is 0.7 (see line 9). The rate is clearly too low, for the usual growth rates for population of the developed regions has been over 1 per cent per year, and to this must be added the allowance for the survival rates from ages 15 through 49. Apparently, World War II and the marked fluctuations of birth rates in many developed regions over the last four to five decades have distorted the age pattern, and, in particular, made for somewhat larger relative numbers among the older age groups within the childbearing span. In the sense that the factors involved were transitory, the contrast between the low implicit growth rates within the female population of the DCs and LDCs is exaggerated, although it is in the expected direction.

Obviously, the much greater numbers in the younger groups, with their markedly higher age specific birth rates, yield a weighted total fertility measure appreciably higher than the unweighted. When we apply, in panel B, the weights derived in panel A, the weighted total fertility measure for the LDCs is 6,606 (line 14, col. 8), compared with the unweighted 5,935 (in line 5, col. 9 of table 1)—a rise of 11 per cent. The shift for the DCs is from 2,880 in table 1 to 2,930 in table 2, a rise of only 2 per cent.

The other link in shifting from the properly weighted total fertility to the crude birth rate is the proportion of all women of childbearing ages to total population (panel A, col. 8). With higher birth rates and rates of natural increase, and, as before, disregarding the possible effects of international migration, the shares of women aged 15–49 in total population might be somewhat lower for the LDCs than for the DCs. And, indeed, the shares are 23 and 24 per cent respectively—but the difference is too slight to offset the differential raising effects on total fertility of the adjustment for the size of the successive age classes within the childbearing span.

With adjusted total fertility, and the share of all women aged 15–49 in total population, we can infer the crude birth rate (panel B, col. 9). For the LDCs, the crude birth rate works out to 43.4 per 1,000; for the DCs to 20.2—a ratio of 2.15, compared with a ratio of unadjusted total fertility in table 1 of 2.06. The inferred birth rates compare well with those given directly in the United Nations sources: for 1960–1964, the weighted average for the LDCs is 42.8 per thousand, for the DCs 19.8—both slightly lower than in table 2, but with the same relative magnitudes.[3] And the regional differentials within the two large groups are about the same, except that here the rate is higher for the Middle East than for Sub-Saharan Africa, and in the United Nations estimates that for Sub-Saharan Africa is higher.

---

[3] The underlying population data here are from the *Demographic Yearbook, 1965* (New York, 1966). The total for the LDCs is the weighted average for the four regions; and the rate for each region is the weighted average of the subregions (Other East Asia, Middle South Asia, and Southeast Asia for East Southeast Asia; Southwest Asia and North Africa for the Middle East; the rest of Africa, except South Africa, for the Sub-Saharan region; and Latin America, excluding the Temperate Zone, for Latin America). For the DCs I took Northern and Western Europe, and Italy, to represent Europe; North America, Australia and New Zealand for the overseas offshoots; and Japan. The crude birth rates for 1960–1964 are given in the sources for table 1; and we used the sum of populations in 1960 and 1964 as weights.

TABLE 2

Age Distribution of Women within the Childbearing Span, and Contribution to Crude Birth Rates, Less Developed and Developed Market Economies, Early or Middle 1960's

A. Number in Successive Age Classes as Relatives of Average Number per Class Within Childbearing Span

	Age Class of Women							Women 15–49 as % of Total Population
	15–19 (1)	20–24 (2)	25–29 (3)	30–34 (4)	35–39 (5)	40–44 (6)	45–49 (7)	(8)
1. East Southeast Asia	1.45	1.31	1.19	0.98	0.82	0.68	0.57	23.1
2. Middle East	1.47	1.32	1.17	0.99	0.80	0.67	0.57	22.5
3. Sub-Saharan Africa	1.53	1.32	1.13	0.96	0.81	0.68	0.56	23.4
4. Latin America	1.53	1.30	1.11	0.97	0.82	0.69	0.57	22.8
5. LDCs	1.48	1.31	1.17	0.98	0.82	0.68	0.57	23.0
6. Europe	1.02	1.04	0.98	1.02	1.09	0.82	1.02	23.9
7. Overseas offshoots	1.12	0.94	0.93	1.02	1.07	0.99	0.92	23.1
8. Japan	1.28	1.16	1.14	1.04	0.91	0.76	0.71	27.0
9. DCs	1.10	1.03	0.99	1.02	1.05–	0.87	0.93	24.1

B. Age Specific Birth Rates, Weighted by Size Relatives of Age Classes

	Age Class of Women							Total Fertility	Implicit Crude Birth Rate
	15–19 (1)	20–24 (2)	25–29 (3)	30–34 (4)	35–39 (5)	40–44 (6)	45–49 (7)	(8)	(9)
10. East Southeast Asia	180	360	333	219	126	44	13	6,375	42.1
11. Middle East	166	403	412	287	159	55	10	7,460	47.9
12. Sub-Saharan Africa	280	389	303	210	124	52	18	6,880	46.0
13. Latin America	185	385	339	236	150	51	13	6,795	44.3
14. LDCs	194	371	338	226	132	47	13	6,605	43.4
15. Europe	33	158	165	108	59	14	1	2,690	18.4
16. Overseas offshoots	66	208	193	128	68	19	2	3,420	22.6
17. Japan	5	126	219	86	20	3	0	2,295	17.7
18. DCs	42	176	185	112	56	14	1	2,930	20.2

C. Contributions to Crude Birth Rate, by Age of Women

	Age Class of Women							
	15–19 (1)	20–24 (2)	25–29 (3)	30–34 (4)	35–39 (5)	40–44 (6)	45–49 (7)	Total (8)
19. East Southeast Asia	5.9	11.9	11.0	7.2	4.2	1.5	0.4	42.1
20. Middle East	5.3	12.9	13.2	9.2	5.1	1.8	0.4	47.9
21. Sub-Saharan Africa	9.5	13.0	10.1	7.0	4.1	1.7	0.6	46.0
22. Latin America	6.0	12.5	11.1	7.7	4.9	1.7	0.4	44.3
23. LDCs	6.4	12.2	11.1	7.4	4.4	1.5	0.4	43.4
24. Europe	1.1	5.4	5.7	3.7	2.0	0.5–	0	18.4
25. Overseas offshoots	2.2	6.9	6.3	4.2	2.3	0.6	0.1	22.6
26. Japan	0.1	4.8	8.6	3.3	0.8	0.1	0	17.7
27. DCs	1.4	6.1	6.4	3.8	1.9	0.5	0.1	20.2
Contribution to Differences in CBR								
28. Line 23 minus line 27	5.0	6.1	4.7	3.6	2.5	1.0	0.3	23.2
29. Line 28 as % of Total	22	26	20	16	11	4	1	100

Notes:

Panel A: Calculated from the 1960 population data by age and sex given in the United Nations working paper cited in the notes to table 1. For line 1 we used the sum of Other East Asia, Middle South Asia, and Southeast Asia: for line 2—

This One
23RB-FL2-D2DF

Having the crude birth rates corresponding to the weighted age specific rates for women, we can calculate the absolute contribution of the births credited to a given age class of women to the aggregate crude birth rate for a given region (panel C). This automatic calculation permits us to observe the age-class origin of the differences in the crude birth rates between any two groups of countries. For our purposes the most interesting is the distribution of the differences in crude birth rates between the LDCs and DCs taken as wholes (lines 28–29).

About six-tenths of the total excess of the crude birth rate of the LDCs over that of the DCs was due to the higher age specific birth rates in the three prime age classes—those from 20 through 34. Over a fifth was due to the higher birth rates of the young, below 20. About a sixth, 16 per cent, was due to the higher birth rates among the older women. Thus the younger and older women combined accounted for almost four-tenths of the differential in the aggregate crude birth rates. To put it differently, if the fertility of younger and older women were the same in the LDCs and DCs, the ratio of the total birth rate of the former to that of the latter would have been 1.7 to 1, not almost 2.2 to 1 as shown in table 2.

Applications of the type just made in table 2, and similar ones measuring the contributions of other characteristics of mothers, fathers, or births, to be made in the sections that follow, are obviously not explanations. They do not indicate the causative factors (decisions by would-be parents, and elements underlying these decisions) that may have been involved in producing the birth rates found. They do, however, *narrow* the locus of the results, and the measures of the different aspects of the parents or of the births may narrow it differently. It is hoped that the causative factors will be more easily perceived, although room will remain for divergent explanatory hypotheses.

3. MARRIED PROPORTIONS, WOMEN

A woman, not naturally sterile, can become a mother, no matter what her marital status: whether single, or divorced, or separated, or widowed, she can, provided she is of childbearing age, have children if she finds a mate. In many countries where legal marriage is prevalent, illegitimate births are distinguished. Conversely, a married woman, even if of childbearing age, does not necessarily have children—voluntary control over intra-marital fertility having become increasingly prevalent particularly in modern societies. Furthermore, in many countries, stable, non-legally certified, common law or consensual marriages are widespread; and these have been included here among marriages and the resulting births classified as legitimate.

We deal here with a social institution, not a biological process. Consequently, we confront a diversity of meanings and institutional framework, particularly in international comparisons that span a wide range of societies. Not only is it difficult to establish comparability for analytical relevance, but the data available are subject to greater error reflecting biases in judgment of respondents in terms of preferred marital status. But the institution does have meaning in the fertility process in most societies. The latter involves long-term union between men and women setting up families as lasting units for the major purpose of having children and rearing them toward independence and adequate status in society at their maturity. If we include consensual or common law marriages as stable unions, as we should, the proportions of total births that are recognized as illegitimate are substantial only in Western societies with a strict legal marriage code and concomitant individual permissiveness.

---

the sum of Southwest Asia and North Africa; for line 3—the sum of Western, Eastern, and Middle Africa; for line 4—the total for Latin America, minus the subtotal for the Temperate Zone. Line 5 was derived from summation of the four regions as defined above. For line 6 we used the sum for Northern, Western Europe, and Italy; for line 7—the sum for North America and Australia-New Zealand. Line 9 was derived from summation of the three regions as defined.

Panel B: Columns 1–7 were calculated by applying to the age specific rates for the regions, the LDCs, and the DCs (in table 1) the relatives shown in the corresponding columns and lines of this table (in panel A). Column 8 is the sum of rates in columns 1–7, multiplied by five (see notes to column 9 of table 1). Column 9 is obtained by dividing the entries in column 8 by 35 (the number of years within the 15–49 span), and multiplying the result by the proper fraction that all women aged 15–49 form in total population (see column 8 of panel A)

Panel C: The shares of the rates for each age class to the total for women 15–49, in columns 1–7 of lines 10–18, were applied to the total crude birth rate shown for each region, for the LDCs, and for the DCs, in column 9 of panel B.

TABLE 3

PROPORTIONS OF MARRIED (INCLUDING CONSENSUAL AND POLYGAMOUS MARRIAGES) WOMEN BY AGE CLASSES, LESS DEVELOPED AND DEVELOPED MARKET ECONOMIES, 1960's

	Number of Countries (1)	Age Classes						
		15–19 (2)	20–24 (3)	25–29 (4)	30–34 (5)	35–39 (6)	40–44 (7)	45–49 (8)
		Less Developed						
1. East Southeast Asia, weighted	11	53.2	82.7	91.5+	90.9	87.5−	79.4	72.0
1*a*. India–Pakistan, weighted	2	70.3	91.8	94.1	91.5−	87.1	77.6	69.8
1*b*. Other countries	9	22.1	66.0	86.8	89.8	88.1	82.6	75.9
2. Middle East	8	34.9	78.6	89.4	91.4	89.4	84.3	77.2
3. Sub-Saharan Africa	14	54.4	86.8	91.4	91.4	89.3	83.8	75.0
4. Latin America	13	17.5+	55.2	73.5	77.7	78.8	75.0	70.0
5. Total, LDCs, weighted		46.7	79.1	88.8	89.2	86.7	79.8	72.7
		Developed						
6. Europe	13	5.0	47.7	79.3	85.7	85.8	83.7	80.4
7. Overseas offshoots	4	9.8	60.1	84.6	88.7	88.6	86.8	83.6
8. Japan	1	1.3	31.4	79.7	88.0	87.5	84.9	79.1
9. Total, DCs, weighted		6.2	49.8	81.4	87.2	87.0	85.1	81.4

Notes:

The underlying data are from United Nations, *Demographic Yearbook, 1968*, and *Demographic Yearbook, 1971* (New York, 1969 and 1972, respectively).

Throughout, the share of married women, for a given age class, was to a total excluding those whose marital status was unknown.

For the weights underlying lines 1, 1*a*, 5, and 9, see the notes to table 1.

The following countries were included, with the year of coverage indicated in parentheses: ***Line 1a***: India (1951), Pakistan (1961); ***line 1b***: Ceylon (1967), Nepal (1961), Indonesia (1964–1965, sample), Khmer (1962), S. Korea (1966), Taiwan (1956), West Malaysia (1957), Philippines (1960), Thailand (1960); ***line 2***: Iran (1966), Turkey (1965), Iraq (1965), Jordan (1961), United Arab Republic (1960), Tunisia (1966), Morocco (1960), Algeria (1966); ***line 3***: Chad (African population 1963–1964, sample), Central African Republic (1959–1960), Angola (1960), Dahomey (African population, 1961), Congo (Kinshasa) (1955–1957), Guinea (1955), Mali (1960–1961), Kenya (1962), Liberia (1962), Madagascar (1966, sample), Senegal (African population, 1961), Togo (1958–1960), Uganda (1963), Zambia (1969); ***line 4***: Costa Rica (1963), Brazil (1970), Guatemala (1964), Honduras (1961), Ecuador (1962), Mexico (1960), El Salvador (1961), Panama (1960), Chile (1970), Colombia (1964), Paraguay (1962), Peru (1961), Venezuela (1961).

For lines 6–8 the coverage is that given in table 1.

For a few countries adjustments had to be made to estimate the proportion for the standard age class (when two were combined, or the lower limit of the youngest class was different from 15 years of age). These adjustments were based on neighboring age classes, or on other countries in the region. The possible errors involved were minor, and it seemed best to include at least the larger countries.

Even so, illegitimate births account for a moderate fraction of total births (ranging up to 15 per cent in Sweden).[4] Furthermore, many illegitimate births may, in leading to long-term, legal marriages, become legitimate retroactively, for all intents and purposes.

Marriage, as defined here, implies a long-term commitment to a union, involves family formation, and also, in the dominant proportion of cases, a commitment to children. Therefore, despite statistical difficulties and ambiguities, it must be considered, and its relevant quantitative aspects summarized. Such a summary, for the marriage proportions among women, by age classes, is provided in table 3.

In general, the proportions of *younger* women who are married are higher in the LDCs than in the DCs. This is particularly true of the 15–19 age class: almost half of all women in the LDCs are married, compared with only 6 per cent in the DCs. It is also true of the 20–24 age class, in which the proportions are close to 80 per cent and about 50 per cent, respectively. Only for women 25 or older are the married proportions in the two groups of countries similarly high. And, in fact, for women 35 or older, the married proportions are higher in the DCs than in the LDCs—largely because the incidence of widowhood is less marked, proportionately, in the former.

---

[4] See e.g. table 21 of United Nations, *Demographic Yearbook, 1969* (New York, 1970), the latest volume emphasizing data on natality. The high proportions of illegitimate births shown for many Latin American countries (and some in Asia) reflect the prevalence of consensual marriages. Since we include consensual with legal marriages, such births must be treated as legitimate.

In addition to this broad, and expected, finding, there are significant differences in the proportions of married women in the younger classes among the several regions within the less developed group; and a question arises about the statistical limitations of those shown for Latin America. The latter are far below those for any other less developed region; and the higher level of economic development in Latin America would not explain this shortfall, since the proportions are lower even for the older age classes. The possible explanation may be that, with the prevalence of consensual marriages in Latin America, there is a marked tendency (stronger among men, but presumably true also of women) by some partners in consensual marriages to report themselves as single.[5] The married proportions in the 15–19 class are distinctly higher for India-Pakistan and Sub-Saharan Africa than for the other countries in East Southeast Asia, Middle East, and Latin America (the latter even allowing for some understatement). These differences conform roughly to the differences in the age specific birth rate for the 15–19 class in table 1—which is higher for India-Pakistan and Sub-Saharan Africa than for the others. Such differences in marriage proportions persist in the 20–24 class, although they are much narrower than in the 15–19 class; and they are apparently too slight to be reflected in the age specific birth rates for the 20–24 class. (Table 1, column 3, lines 1–4, shows no significant differences in birth rates for this age class among the several regions.)

Since in the comparison of the LDCs with the DCs, the differentials in marriage proportions in the younger classes among women are roughly consonant with differences in fertility levels, we related the age specific birth rates for age classes of all women to the married proportions, deriving age specific marital fertility rates. These are given in table 4, lines 1 and 2.

Obviously, we introduced an error in relating all births, including illegitimate, in a given age class of women to the married proportions within that age class. The ratios overstate marital fertility, particularly in the ages in which marriage proportions are low and the ratios of all mothers to married mothers are high. But the exaggeration should affect both the LDCs and the DCs, and its impact is reduced by combining the two young classes—15–19 and 20–24—with due allowance, of course, for the difference in size, total and married.

Because of the striking, and suspect, differences in age specific marital fertility in the two young classes taken separately, we combine them. For the two combined, or up to age 25, the age specific fertility adjusted for the difference in married proportions is no higher among the LDCs than among the DCs—if anything, it is significantly lower, although some allowance must be made for differential errors in exaggeration (lines 1 and 2). To put it differently, the age specific fertility in the LDCs up to age 25 (cumulatively) is higher than that in the DCs only in association with the much higher marriage proportions, i.e. the earlier incidence of marriage among the women in the LDCs than in the DCs. Only in the older ages, when the marriage proportions in the LDCs no longer rise, and those in the DCs catch up, do differences in marriage proportions cease to have any effect on the age specific fertility rates for women, or rather on the differentials between these rates for the LDCs and the DCs.

The finding is hardly surprising. Indeed, it is, in a way, a necessary consequence of the difference in marriage incidence at the younger ages between the LDCs and DCs. If in the DCs marriage proportions at the early ages are low—and they were below 50 per cent through the ages of 21–23—those women who did marry were likely to be a group with a high propensity toward having children or high fecundity, or both. The much wider groups of young married women in the LDCs would, therefore, be unlikely to match the marital fertility rates of these early starters among the young women in the DCs. It is the dominant proportion of married women that is the primary cause of the higher marital fertility of the LDCs. And yet the finding is of cardinal importance in interpreting the birth rate differen-

---

[5] See discussion of table on marital status (table 7) in United Nations *Demographic Yearbook, 1968* (New York, 1969), pp. 21–22.

TABLE 4

Births per 1,000 Married Women, and Effects of Differences in Marriage Proportions versus Differences in Births per 1,000 Married Women on Differences in Fertility between Less Developed and Developed Market Economies

	Age Classes of Women								
	15–19 (1)	20–24 (2)	15–24 (3)	25–29 (4)	30–34 (5)	35–39 (6)	40–44 (7)	45–49 (8)	Total (9)
				Total Births, per 1,000 Married Women					
1. LDCs	281	374	326	325	259	186	86	32	nc
2. DCs	613	344	374	230	126	61	19	1	nc
				Effect of Differences in Proportions of Married Women					
3. Assumed identical birth rates per 1,000 married women			350	278	193	124	53	17	nc
4. Married proportions, LDCs (%)			61.9	88.8	89.2	86.7	79.8	72.7	nc
5. Married Proportions, DCs (%)			27.3	81.4	87.2	87.0	85.1	81.4	nc
6. Derived age specific BRs, LDCs			217	247	173	108	42	12	5,080
7. Derived age specific BRs, DCs			96	226	168	108	45	13	3,760
8. Derived BRs, LDCs, weighted by relative size of age class			605	289	170	88	29	7	5,940
9. Derived BRs, DCs, weighted by relative size of age class			204	221	171	113	39	12	3,800
				Effect of Differences in Births per 1,000 Married Women					
10. Assumed identical marriage proportions (%)			44.6	85.1	88.2	86.8	82.5	77.0	nc
11. Derived age specific BRs, LDCs			145	277	228	161	71	25	5,310
12. Derived age specific BRs, DCs			167	196	111	53	16	1	3,555
13. Derived BRs, LDCs, weighted by relative size of age class			395	324	223	132	48	14	5,680
14. Derived BRs, DCs, weighted by relative size of age class			356	194	113	56	14	1	3,670

Allocation of Differences in Total Fertility Between LDCs and DCs

	Aggregate Differences (1)	Effects of Differences in Marriage Proportion (2)	Effects of Differences in Births per Married Woman (3)
15. Total fertility not weighted	3,055	1,320	1,755
16. Total fertility weighted	3,635	2,140	2,010

nc—not calculated.

Notes:

Lines 1 and 2: For the standard size classes obtained by dividing the age specific birth rates in table 1 (lines 5 and 9) by the marriage proportions (treated as proper fractions) in table 3 (lines 5 and 9). For the 15–24 class (column 3), we derived the joint age specific rate (analogous to that in table 1) by using the weights of the two classes (15–19, and 20–24) as given in the relevant columns and lines of table 2; calculated the joint marriage proportion by using the weights for the two classes again from table 2; and then divided the joint age specific birth rate by the joint marriage proportion.

Line 3: Arithmetic means of the BRs in lines 1 and 2.

tials between the LDCs and the DCs. To the extent that these differentials in the early ages are so closely associated with differences in marriage proportions, the finding emphasizes the early entry of women into the childbearing family and the early withdrawal of such women from outside activities. Indeed, in many LDCs, a young woman, sheltered in her parental home, moves immediately to marriage, without participating directly in any non-domestic activity through much of her youth and childbearing span. Thus, some light is shed on the structure of the family, particularly with regard to the ages and experiences of wife and husband. We shall find below that this early entry into marriage is not typical of men in the LDCs; and that the age difference between husbands and wives is significantly wider in the LDCs than in the DCs.

Given the age specific birth rates per 1,000 married women, and the proportions which relate married to all women by age classes, the differences in total fertility between the LDCs and the DCs can be decomposed—into those differences due to marriage proportions (for identical marital fertility ratios) and those due to marital fertility (for identical marriage proportions in the comparable age classes of women). The calculation appears in lines 3–14 of table 4; and the summary of the two sets of effects on unweighted total fertility, or on total fertility weighted as it was in table 2, is shown in lines 15 and 16.

The sum of the two sets of effects does not equal the total, particularly in line 16, because of intercorrelation between marriage proportions and age specific marital fertility. And there are, of course, the limitations already noted on the use of total births in relation to married women. But the rough magnitude of the findings would be little affected by refinements. The general suggestion is that between four-tenths and a half of the difference in total fertility between the LDCs and DCs is due to differences in marriage proportions; and the balance to intra-marital fertility differences. These weights should be taken only as a general indication that differences in marriage proportions, among younger women, play a large part, if we assume that early marriage is a *pre-condition* of the wide age specific birth rate differences in the ages below 25 and 30. Indeed, it follows automatically from the two findings already noted: (1) that excess of birth rates for the age group below 30, either in table 1 or table 2, would account for about a half of the total fertility differentials; (2) that up to the age between 25 and 30 the higher birth rates of women in the LDCs are completely accounted for by their higher marriage proportions. In this sense, the evidence in the present section is a refinement, a detail in understanding how the much higher age specific birth rates for the younger women in the LDCs are attained.

4. MARRIED PROPORTIONS, MEN, AND DISTRIBUTION OF BIRTHS BY AGE OF FATHER

We are concerned here with two questions. The first relates to the ages of married men compared with those of their wives, for the LDCs and the DCs. We shall find that women who marry at an early age marry much older men in the LDCs, and the excess of a husband's age over that of his wife is far wider than in the DCs. Obviously then the structure within the family household differs in the two groups of countries. The decision activity of a household composed of an older husband and a younger wife must differ from that of a household in which the ages, and implicitly experience in the outside world, of husband and wife do not differ as much. The second question concerns the distribution of births

---

Lines 4 and 5: From table 3, lines 5 and 9, with the calculation for the joint class (15–24) as indicated above.

Lines 6 and 7: Birth rates in line 3 multiplied by the married proportions in lines 4 and 5 (treated as proper fractions). Total fertility in column 9 is five times the sum of the class fertilities (with that for 15–24 multiplied by two).

Lines 8 and 9: The weights for the relatives of the size classes are from table 2, lines 5 and 9. These are applied to the derived age specific BRs in lines 6 and 7. Total fertility (column 9) is five times the sum of the entries in columns 3–8 (with that for column 3 multiplied by two).

Line 10: Arithmetic means of the married proportions in lines 4 and 5.

Lines 11 and 12: The BRs given in lines 1 and 2, respectively, multiplied by the assumed marriage proportions (treated as proper fractions) in line 10.

Lines 13 and 14: The age specific birth rates, derived for the age classes in lines 11–12, are weighted by the relative size of these classes, given in table 2, lines 5 and 9.

Lines 15 and 16: Column 1: differences between total fertility of LDCs and DCs, unweighted (from lines 5 and 9, column 9 of table 1); and weighted (from lines 14 and 18, column 8, table 2). Column 2: differences between lines 6 and 7, column 9; and lines 8 and 9, column 9. Column 3: differences between lines 11 and 12, and 13 and 14, column 9.

TABLE 5

Married Proportions and Age Partition Values for Distributions of Married Men and Women and of Births by Age of Mother and Father, Less Developed and Developed Countries, 1960's

A. Married Proportions for Men (and Women, Comparable Coverage)

	Age Classes						
	15–19 (1)	20–24 (2)	25–29 (3)	30–34 (4)	35–39 (5)	40–44 (6)	45–49 (7)
LDCs							
1. Men	11.2	40.9	69.5—	85.8	89.7	89.7	89.1
2. Women (comparable coverage)	42.6	75.9	87.9	88.7	86.2	79.1	73.7
DCs							
3. Men	1.1	24.6	65.2	82.5	86.6	88.0	88.2
4. Women (comparable coverage, table 3)	6.2	49.8	81.4	87.2	87.0	85.1	81.4

B. Partition Values for Panel A

	LDCs			DCs		
	1st quart. (1)	Median (2)	3rd quart. (3)	1st quart. (4)	Median (5)	3rd quart. (6)
5. Wives, 15–49, comparable coverage	23.4	29.7	37.6	28.7	35.4	42.2
6. Corresponding married men (husbands, see text)	28.7	36.6	46.9	31.5	38.3	45.5
Age differentials between LDCs and DCs						
7. Wives (line 5)				−5.3	−5.7	−4.6
8. Husbands (line 6)				−2.8	−1.7	1.4
9. Age excess, husbands over wives (line 6 minus line 5)	5.3	6.9	9.3	2.8	2.9	3.3

C. Partition Values, Wives and Mothers (based on Tables 2 and 3)

	LDCs			DCs		
	1st quart. (1)	Median (2)	3rd quart. (3)	1st quart. (4)	Median (5)	3rd quart. (6)
10. Wives, 15–49	23.1	29.5	37.4	28.7	35.4	42.2
11. Mothers, 15–49	21.8	26.4	31.9	23.0	27.0	31.6
Age differentials between LDCs and DCs						
12. Wives (line 10)				−5.6	−5.9	−4.8
13. Mothers (line 11)				−1.2	−0.6	0.3
14. Lead of age partition values, mothers over wives (line 11 minus line 10)	−1.3	−3.1	−5.5	−5.7	−8.4	−10.6

D. Derivation of Age Partition Values, Distribution of Births by Age of Father

15. Corrected partition values, married men (line 10 + line 9)	28.4	36.4	46.7	31.5	38.3	45.5
16. Alternative partition values, married men (using median difference only)	30.0	36.4	44.3	31.6	38.6	45.1
17. Partition ages, fathers (line 15 + line 14)	27.1	33.3	41.2	25.8	29.9	34.9
18. Alternative partition ages, fathers (line 16 plus line 14)	28.7	33.3	38.7	25.9	29.9	34.5
Age differentials between LDCs and DCs						
19. Line 17				1.3	3.4	6.4
20. Line 18				2.8	3.4	4.3

by age of father. If, in general, husbands are older relative to their wives in the LDCs than in the DCs, and if, as already observed, childbearing continues to older women (within their childbearing span) in the LDCs than in the DCs, the contribution of older fathers to the crude birth rate must be far greater in the LDCs than in the DCs. And we shall find that a substantial proportion of births in the LDCs can be credited to fathers of 40 years or over. This finding sheds further light on the determinants of the higher birth rates in the LDCs.

Unfortunately, the available data do not directly yield the comparisons and distributions that we seek. Some manipulation and restrictive assumptions must be made before even approximate answers can be reached. Yet the statistical difficulties are of interest in themselves because they reflect substantial international differences in the marriage institutions and differences in the degree of connection of children to their fathers compared with that of children to their mothers.

We begin with the marriage proportions of men, that are to be compared with marriage proportions of women, both for comparable age classes. Our intent is to derive, for comparison with the distribution of married women aged 15–49, a distribution of their husbands by age. In this attempt, we immediately run into difficulties. In the first place, for many less developed countries (but for none of the developed), the reported number of married men is significantly short of the reported number of married women despite the inclusion of the consensually married. The remaining categories are single, widowed, and separated. Yet if reporting is accurate, if polygyny is not practiced, and if differential international migration (in which case shortages of husbands in some countries would be offset by excesses in others) is disregarded, the numbers of all married men and women (albeit of different ages) should be identical.

The explanation is, in good part, that polygyny is practiced in many countries. In fact, for several Sub-Saharan countries, the United Nations *Demographic Yearbooks* report numbers of men with two wives, three wives, and so on; and for several Middle Eastern Moslem countries they report marriages of men already married. The shortage of husbands reported for Latin America, where consensual marriages are common, suggests that some polygynous marriages

---

Notes:

Lines 1–2: The sources of data for individual countries are those cited in the notes to table 3. For reasons given in the text only those countries were used for which the total numbers of married women and men for the given year differed by only a few per cent (well below 10). The following countries were included: for East Southeast Asia (10)—Ceylon, Indonesia, Khmer, S. Korea, Taiwan, India, West Malaysia, Pakistan, Philippines, and Thailand—with the usual weighting within the region; for the Middle East (8)—Iran, Turkey, Iraq, Algeria, Libya, Tunisia, Morocco, and UAR; for Sub-Saharan Africa—none; for Latin America (11)—Brazil, Chile, Mexico, Colombia, Costa Rica, Guatemala, Honduras, Panama, Paraguay, Peru, and Venezuela. The usual weighting by total population in 1960 was followed in combining the three major regions covered.

Lines 3–4: Coverage is that given in the notes to tables 1 and 3, from the same sources.

Line 5: The product of the proportions married within the successive age classes, 15–49 (in lines 2 and 4 above) and the relative weight of each age class (from table 2, lines 5 and 9) is the distribution of married women, 15–49, by five-year age classes. The use of class weights of all LDCs, from table 2, is justified because the relative weights of the age classes in the omitted region (Sub-Saharan Africa) are quite close to those of the LDCs as a whole (see table 2, lines 3 and 5). From the distributions we derive, by linear interpolation, the three age partition values shown.

Line 6: The basic assumption here is that younger husbands are matched with younger wives. Knowing the distribution of married men and of married women, for the same countries and years, we can then calculate the partition age of husbands *corresponding* to the partition age of wives. The weights for age classes among men used in the calculation were the same as those for age classes among women. The close similarity of the two is shown in the distributions for large regions in the UN Working Paper cited in the notes to panel A of table 2.

Line 10: The underlying proportions of married women within each age class are from table 3, lines 5 and 9. The relative weights are from table 2, lines 5 and 9; and the procedure is the same as that for line 5 above.

Line 11: Table 2, lines 23 and 27 show the contribution of each age class within the total of all women 15–49 to the crude birth rate (or to total births), for the LDCs and DCs, respectively. From these two distributions we derive, again by linear interpolation, the age partition values. Since we are assuming that all births are by married women, the distributions of births by age of mother and by age of married mother are identical.

Line 16: Instead of matching the youngest husbands to the youngest wives (as was done for line 6 above), which yields a widening excess of age of husband over age of wife as the age of wives increases, here we assume a constant age differential between husbands and wives and set it at the differential at the median partition value. An element of matching younger husbands to younger wives still remains, but only in the sense that for all wives, 15–49, the younger group of husbands (in equal number) is selected among the total of married men. But there is no selectivity *within* the age span of wives 15–49.

are also included. The alternative, and contributory assumption, is that even when a consensual marriage is monogamous, there is a greater tendency among men than among women not to report themselves as married.

We must match husbands and wives, for married women in their childbearing ages, and compare the ages of husbands and wives, since they affect decisions regarding children, and in order to derive distributions of births by age of father. For this purpose only monogamous marriages can be handled easily. We have, therefore, excluded from lines 1 and 2 of table 5 all countries in which number of married men fell short of that of married women by more than a few percentage points (there were no opposite pairings). This meant eliminating all Sub-Saharan African countries (except Madagascar, which would not contribute much); and also many Latin American countries. As already indicated, this problem did not arise in the case of the DCs. Although illegitimate births and informal departures from monogamy do occur, they are not legally recognized, nor are they recorded in any way within the statistically established marital status categories. The exclusion of polygynous marriages from the LDC estimates probably leads to an understatement of the excess of the age of husbands over that of wives. The weighted excess of a husband's age over that of all of his *several* wives would presumably be greater than the excess in monogamous pairings. A man usually acquires his second or third wife as he grows older and his economic status improves. Moreover, he usually selects much younger second and third mates.

But we have to go beyond the married proportions for men and women separately, toward some approximation to the relative ages of wives and their husbands. For this purpose the age distribution of married men must be linked to that of married women. No problem would arise if data were available on the cross-classification of married couples by ages of husband and wife; or if data on the ages of brides and grooms at time of marriage were available, cross-classified, for an adequate sample of countries. But neither body of data is provided in the international compilations of demographic information; and a search in the records of individual countries was not practicable here. Hence we attempted an approximation by the use of some plausible assumptions (panel B).

The distributions of married women, 15–49, by age class, can be derived from marriage proportions and the data in table 2 on the relative size of each age class; and the quartiles and medians in line 5 can then be estimated directly. These estimates show that the quartile and median ages of married women (within the childbearing span) in the LDCs are about five years below those in the DCs (line 7). But we would like a similar set of partition values for the married men, who can be viewed as husbands of the married women aged 15–49, since these men are the most involved in decisions on the production of the next generation. The *corresponding* partition values for married men (husbands) in line 6 are derived on the assumption that younger married men should be matched with younger married women—perhaps the most plausible of alternative simple assumptions. Using this principle in matching and having the age distribution of married men, we assign a number equal to that of the first quartile of the distribution of married women—to establish the age partition value that separates this number from all other, older married men; and continue up the age scale for married women, and correspondingly, married men.

Three related conclusions emerge. First, whereas married women, age 15–49, were about 5 years younger in the LDCs than in the DCs, the husbands of these women in the LDCs were only slightly younger at the median than the husbands in the DCs (less than 2 years); and at the third quartile of the distribution they were distinctly older (lines 7 and 8). Second, the age excess of husbands over wives (the latter aged 15–49) was much wider in the LDCs than in the DCs: at the median about 7 years for the former and about 3 years for the latter (line 9). Third, the age excess of husbands over wives in the LDCs rises markedly from the younger to the older ages of wives (still within the 15–49 span) —from 5.3 at the first quartile to 9.3 at the third; whereas the age excess of husbands in the DCs increases only slightly—from 2.8 at the first quartile to 3.3 at the third (line 9).

These conclusions are subject to two qualifications: the limited coverage of the LDCs and, particularly, the assumption underlying the "matching" of husbands and wives. It is this assumption, applied *within* the age distribution of married women, that produces the steep rise in excess of age of husband for the LDCs. On the other hand, the omission of Sub-Saharan Africa may have resulted in understating the age excess of husband over wife in the LDCs. Consequently, the general order of magnitudes is likely to stand. To put it briefly, the age excess of husbands over wives is probably significantly wider in the LDCs than in the DCs, particularly at the older ages; the average ages of husbands of wives aged 15–49 are not too different in the LDCs and the DCs; and the wives are distinctly younger in the former than in the latter.[6]

The contrast in ages of wives and husbands in the LDCs and those in the DCs is of interest in itself. It suggests a difference in the structure of the household, at least as far as the parental generation is concerned. But it also is an indirect indication of the distribution of births by age of father, from which we can infer the contribution of older fathers to the difference in crude birth rates between the LDCs and the DCs. Panels C and D of table 5 show the results of an attempt to link the age distributions of married men and women with the distributions of births by ages of fathers and mothers. The underlying assumption is that births are related to married men and women, and illegitimate births are disregarded. However, the latter are clearly definable, and of some limited importance, only in the DCs.

In panel C we link the distribution of married women with that of married mothers (unmarried mothers having been excluded by assumption). For the LDCs the distribution of married women underlying the partition values shown in line 10, columns 1–3, is from tables 2 and 3, and includes all regions—much more complete coverage than that in line 5—which explains the slight difference between the two sets of partition values in lines 5 and 10. This minor discrepancy suggests that the limitation of coverage for the LDCs in panels A and B was not of great consequence. Panel C indicates, as one would expect, that the population of current mothers is distinctly younger than the population of current wives, aged 15–49, reflecting the higher age specific birth rates for the younger age classes, particularly those under 35 (line 14). Since the

---

[6] Some confirmation of the findings is suggested by the rather meager data on age distributions of brides and grooms in the LDCs (compared with the DCs). For five countries in the Middle East and six countries in Latin America we have the median ages of brides and grooms and those of married men and women (consensual marriages excluded)—both groups covered only through age classes 15–49. In the tabulation below we compare these with similar data for twelve countries in the DC group.

Median Ages of Brides and Married Women, and of Bridegrooms and Married Men, LDCs and DCs, 1960's
(for brides and wives below 50)

	Median age, bride (1)	Corresponding age, groom (2)	Difference (2–1) (3)	Median age, wife (4)	Corresponding age, husband (5)	Difference (5–4) (6)
1. Middle East, 5 countries	20.3	26.3	6.0	31.1	39.2	8.1
2. Latin America, 6 countries	22.0	26.2	4.2	32.1	37.2	5.1
3. ME and LA	21.2	26.2	5.1	31.6	38.2	6.6
4. Developed countries	22.7	25.4	2.7	35.3	38.2	2.9

Notes:

Underlying data are from United Nations, *Demographic Yearbook, 1968* (New York, 1969), table 27 (for age at marriage) and table 7 (for distribution by age and marital status).

In general, the year of marriage was assumed to lie between 3 and 5 years before the year for which marital status was reported.

Countries covered in the Middle East are Iraq, Jordan, United Arab Republic, Tunisia, and Algeria; for Latin America—Mexico, Colombia, Peru, Guatemala, Chile, and Venezuela. The consensual category was omitted and the two regions were weighted equally.

The DCs covered are the eight largest countries in Europe, all overseas offshoots except New Zealand, and Japan. The weights for the three regions were those used in the text tables. In deriving the age partition values for men corresponding to the median age of bride (wife), we matched younger grooms (husbands) with younger brides (wives). For *medians* this implies no *internal* matching within the age distribution, since the full range of the younger grooms (husbands) is assumed to correspond to the total 15–49 range of brides (wives).

Both the excess of age of husband over wife and the excess of age of groom over that of bride are wider in the LDCs than in the DCs. Moreover, the spread is somewhat wider for ages of wives and husbands than for ages of brides and grooms in the LDCs (from 5.1 to 6.6 years), not true of DCs (where it changes from 2.7 to 2.9 years). The wife-husband population is, of course, older than the bride-groom—and the widening of the excess of ages of husband over wife, compared with groom over bride, suggests the tendency observed in table 5, for the excess of the age of husband over wife to rise as the wife grows older—particularly notable in the LDCs, but rather minor in the DCs.

Needless to say, because countries in East Southeast Asia (particularly India, Pakistan, and Indonesia) and in Sub-Saharan Africa are omitted, the median age for the bride among the LDCs in the tabulation just shown is too high. Hence, the difference between the LDCs and the DCs in the median age of brides in lines 3 and 4, col. 2 is underestimated.

concentration of childbearing within the prime age classes, 20–34 among the married women is greater in the DCs than in the LDCs, and since married women are, on the average, older in the DCs, the lead of age partition values of mothers over wives is far wider in the DCs than in the LDCs—over 8 years compared with 3 years at the median respectively (see line 14 again).

In panel D we apply the differentials in the age partition values between wives and mothers to the estimated age partition values of husbands, to derive the age partition values for fathers. The

TABLE 6

Distributions of Births by Age of Mother and of Father, Selected Groups of Countries, Late 1950's and Mid-1960's (percentages)

A. Distribution of Births

	Age Classes of Mothers and Fathers							
	Below 20 (1)	20–24 (2)	25–29 (3)	30–34 (4)	35–39 (5)	40–44 (6)	45 & over (7)	Total (8)
Less Developed Countries								
Taiwan and Philippines								
1. Mothers	5.8	26.1	29.1	20.7	12.8	4.7	0.8	100
2. Fathers	1.1	14.4	27.0	24.3	17.2	9.8	6.2	100
3. Line 2 − line 1	−4.7	−11.7	−2.1	3.6	4.4	5.1	5.4	37.0
Middle East (3 countries)								
4. Mothers	8.3	21.8	26.0	21.4	14.6	6.1	1.8	100
5. Fathers	0.4	7.1	19.0	22.5+	20.0	13.5	17.5	100
6. Line 5 − line 4	−7.9	−14.7	−7.0	1.1	5.4	7.4	15.7	59.2
Latin America (6 countries)								
7. Mothers	14.3	29.4	24.2	16.6	11.0	3.7	0.8	100
8. Fathers	2.3	18.6	24.6	21.0	15.0	9.3	9.2	100
9. Line 8 − line 7	−12.0	−10.8	0.4	4.4	4.0	5.6	8.4	45.6
Average of ME and LA (equal weights)								
10. Mothers	11.3	25.6	25.1	19.0	12.8	4.9	1.3	100
11. Fathers	1.3	12.9	21.8	21.8	17.5	11.4	13.3	100
12. Line 11 − line 10	−10.0	−12.7	−3.3	2.8	4.7	6.5	12.0	52.0
Developed Countries								
Europe (10 countries)								
13. Mothers	4.9	26.3	31.3	21.9	11.7	3.5	0.4	100
14. Fathers	0.7	13.8	30.7	26.2	15.9	7.8	4.9	100
15. Line 14 − line 13	− 4.2	−12.5	−0.6	4.3	4.2	4.3	4.5	34.6
Overseas Offshoots (3 countries)								
16. Mothers	8.9	31.5	29.4	17.8	9.4	2.8	0.2	100
17. Fathers	1.6	18.3	30.5	24.3	14.7	6.9	3.7	100
18. Line 17 − line 16	−7.3	−13.2	1.1	6.5	5.3	4.1	3.5	41.0
Japan								
19. Mothers	1.2	27.2	43.3	20.2	6.6	1.4	0.1	100
20. Fathers	0	7.5	39.4	33.1	12.4	5.1	2.5	100
21. Line 20 − line 19	−1.2	−19.7	−3.9	12.9	5.8	3.7	2.4	49.6
All Developed (weighted average)								
22. Mothers	5.8	28.4	32.5	20.1	10.0	2.9	0.3	100
23. Fathers	0.9	14.5+	32.0	26.6	14.9	7.0	4.1	100
24. Line 23 − line 22	−4.9	−13.9	−0.5	6.5	4.9	4.1	3.8	38.6

B. Age Partition Values in the Distribution of Births, Mothers and Fathers

	Taiwan & Philip. (1)	Middle East (2)	Latin Am. (2)	LA & ME (4)	Europe (5)	Ov. off. (6)	Japan (7)	DCs (8)
Mothers								
25. 1st quartile	23.7	23.8	21.8	22.7	23.8	22.6	24.3	23.4
26. Median	28.1	28.8	26.3	27.6	28.0	26.6	27.5	27.4
27. 3rd quartile	33.4	34.4	32.1	33.4	32.9	31.5	30.8	32.1
Fathers								
28. 1st quartile	26.6	29.6	25.8	27.5	26.7	25.8	27.2	26.5
29. Median	31.5	35.2	31.1	33.2	30.9	92.9	30.5	30.5
30. 3rd quartile	37.4	42.2	37.8	39.9	36.1	35.1	34.2	35.3
Excess of Age of Fathers								
31. 1st quartile	2.9	5.8	4.0	4.8	2.9	3.2	2.9	3.1
32. Median	3.4	6.4	4.8	5.6	2.9	3.3	3.0	3.1
33. 3rd quartile	4.0	7.8	5.7	6.5	3.2	3.6	3.4	3.2

Notes:

The distributions of births by age of mothers and of fathers are for identical countries for the same year. Column 8 of lines 3, 6, 9 . . . 24, is the sum of columns 1–7, signs disregarded.

The data for the LDCs are largely from United Nations, *Demographic Yearbook, 1969* (New York, 1970), tables 14 and 19. Taiwan is the one country for an earlier year, 1958, from *Demographic Yearbook, 1959* (New York, 1959), tables 11 and 13.

Lines 1–2: Includes the Philippines (1964) and Taiwan (1958).

Lines 4–5: Includes Algeria (1965), Tunisia (1965), and the United Arab Republic (1966).

Lines 7–8: Includes Puerto Rico (1963), Peru (1963), Chile (1963), Guatemala (1936), and Costa Rica and Panama, combined (1963). Many Latin American countries also reporting had to be omitted because in the distribution by age of father, the unallocated births were more than 20 per cent of the total.

Lines 13–14: Because of inadequate coverage of Europe in later years, we had to use data on legitimate births for 1957 or 1958, given in the *Demographic Yearbook, 1959*. The only country included for a recent year (total births, 1963) was England and Wales.

The following countries were included: Austria (1958), Belgium (1958), Denmark (1957), Finland (1958), France (1958) Germany (Federal Republic, 1955), Netherlands (1958), Norway (1957), Sweden (1957), and England and Wales (1963)

Lines 16–17: Includes Canada (1958), United States (1955), and Australia (1963).

Lines 19–20: For 1957.

Lines 22–23: The weights used are population for 1960 (see notes to table 1).

Lines 25–30: Derived by linear interpolation from the percentage distributions in panel A.

assumption underlying this calculation is that the age excess of husband over wife, for a given age class of the latter, is identical with that of father over mother within the given age class of wife. However, if, e.g. wives age 20–24 have husbands who are 25–29 (i.e. five years older), the current mothers among these wives (say a quarter of them) may have husbands who are *more* or *less* than five years older. Unfortunately, we have no basis for adjusting the age differential between husband and wife to that between father and mother. In any case, the adjustment is not likely to be *substantial*. Moreover, the distribution of births by age of father in lines 17 and 18 will be checked by alternative sets of data in following tables.

Line 17 allows for internal "matching" whereas for line 18 we assumed a constant excess of age of husband within the range of married women 15–49—an assumption somewhat less realistic than that used in other panels, but one that reduces the effect of the matching assumption. Still, the differences between the two lines are so slight that they suggest the same conclusion.

The conclusion is that fathers of about 40 or over contribute a quarter of all births in the LDCs. Thus, in the latter, with the crude birth rate at 43.4 per 1,000, a component of 10.85 is to be credited to these fathers. In the DCs, the age partition value for fathers at the third quartile is below 35 years; and it seems reasonable in the light of other evidence to suggest that fathers aged 40 and over can be credited with about one-tenth of all births. With a crude birth rate of 20.2, the contribution of the older fathers in the DCs is then 2.02. The difference between the contributions of older fathers in the LDCs and DCs is then 10.85 minus 2.02, or 8.83, out of a total difference in the crude birth rates of 23.2 points, or well over a third. This finding differs markedly from that for mothers. Mothers aged 40 or more account for only 1.3 out of 23.2 points of total difference; and even women aged 35 and over contribute only a seventh of the total difference in crude birth rates between LDCs and the DCs (see table 2, line 28).

The contribution of older fathers can be checked with an alternative set of data, also incomplete, but in other ways. For eleven less developed countries we have for recent years distributions of births by age of father, which can be compared with the distributions by age of mother. Similar data are available for all developed countries, but for the 1950's, not the 1960's; and for legitimate births only. The evidence is summarized in table 6.

Regrettably, we have no data for the populous Asian countries, like India and Pakistan, or for Sub-Saharan Africa, both regions with high specific birth rates in the younger age classes of women. We use Middle East and Latin America, weighted equally (since the structure of the former is closer to the missing regions), to represent the LDCs. This approach, while understating the excess of ages of fathers over those of mothers, may nevertheless yield a good approximation of the share of older fathers in total births.

The share of fathers aged 40 and over in the distribution of births by age of fathers for the average of ME and LA, is about a quarter (line 11). This finding checks with that indicated by the age partition values established in table 5. By contrast, the share of fathers 40 or older in total births in the DCs is about 11 per cent, which also checks with the finding based on table 5 (line 23).

In comparing directly the shares in total births of fathers and mothers of identical age classes (lines 3, 6, and so on of panel A), or in comparing the age partition values derived from the distributions of births by ages of fathers and mothers, we are implicitly matching younger fathers and mothers. Since this plausible assumption is used also in connection with table 5, we can compare the differentials in age partition values between mothers and fathers, with those obtained in comparing wives and husbands in table 5. There the age excess of husbands over wives, for the LDCs, was 5.3 years at the first quartile, 6.9 years at the median, and 9.3 years at the third quartile; for the DCs it was 2.8, 2.9, 3.3 years respectively (see table 5, line 9). In table 6, the age excess of fathers over mothers, for the average of the Middle East and Latin America, is 4.8 years at the first quartile, 5.6 years at the median, and 6.5 years at the third quartile; while the corresponding differentials for the DCs are 3.1, 3.1, 3.2 years (lines 31–33, columns 4 and 8). For the DCs the differentials between the age partition values of husbands and wives are about the same as between those of fathers and mothers, although the average ages of wives and husbands differ from those of mothers and fathers. For the LDCs the age excess of fathers over mothers in table 6 is narrower than that of husbands over wives in table 5, but the difference may be due partially to inadequate coverage in table 5. Yet table 6 confirms, for fathers and mothers, the finding for husbands and wives in table 5: the age excess of men is much wider in the LDCs than in the DCs, and it increases more significantly in the former as the age of wife or mother rises.

On the basis of table 6, and the assumption that the average for the Middle East and Latin America represents the LDCs, we derive the distributions of births by the quinquennial age classes of fathers, as we did for mothers in table 2. We then calculate the contributions of each age class to the differences in crude birth rates between the LDCs and DCs (table 7).

The finding here confirms the inference from table 5 that the contribution of fathers aged 40 and over is so much greater in the LDCs than in the DCs that it accounts for one-third of the total difference between the crude birth rates of the two groups of countries. In table 2 we found that *young* mothers, those below the age of 20, contributed more than a fifth of the total difference between the crude birth rates of the LDCs and the DCs (see table 2, line 29). Assuming little overlapping between husbands 40 and over and wives below the age of 20, one could say that if the age specific birth rates for women below age 20 and for men 40 or more were the same in the LDCs and the DCs, the difference in the crude birth rates between the two groups of coun-

TABLE 7

Distribution of Births by Age of Father, Less Developed and Developed Market Economies, 1950's and 1960's

	Age of Mother or Father							
	Below 20 (1)	20–24 (2)	25–29 (3)	30–34 (4)	35–39 (5)	40–44 (6)	45 & over (7)	Total (8)
% Shares of Births by Age of Mother (lines 1–4)								
1. Middle East	11.1	27.0	27.6	19.2	10.7	3.7	0.7	100
2. Latin America	13.6	28.3	25.0	17.4	11.0	3.8	1.0	100
3. ME and LA (equal weights)	12.4	27.6	26.3	18.3	10.8	3.7	0.9	100
4. LDCs	14.6	28.1	25.6	17.1	10.0	3.6	1.0	100
5. Differences in % shares of births, age of father minus age of mother, ME and LA	−10.0	−12.7	−3.3	2.8	4.7	6.5	12.0	0
6. Derived % shares of births by age of father (line 4 + line 5)	4.6	15.4	22.3	19.9	14.7	10.1	13.0	100
7. % shares of births by age of mother, DCs	7.2	30.0	31.6	19.1	9.5	2.4	0.2	100
8. Differences in % share of births, age of father minus age of mother, DCs	−4.9	−13.9	−0.5	6.5	4.9	4.1	3.9	0
9. Derived % shares of births by age of father, DCs (line 7 + line 8)	2.3	16.1	31.1	25.6	14.4	6.5	4.0	100
Contributions to Differences in Crude Birth Rates, Age Classes of Fathers								
10. LDCs	2.0	6.7	9.7	8.6	6.4	4.4	5.6	43.4
11. DCs	0.5	3.2	6.3	5.2	2.9	1.3	0.8	20.2
12. Contributions to differences	1.5	3.5	3.4	3.4	3.5	3.1	4.8	23.2
13. % Distribution of line 12	7	15	15	15	15	13	20	100

Notes:

Lines 1, 2, and 4: Calculated from table 2, lines 11, 13, and 14.

Line 5: From table 5, line 12.

Line 7: From table 2, line 18.

Line 8: From table 5, line 24.

Lines 10–13: Shares in lines 6 and 9 applied to total crude birth rates for the LDCs (43.4 per 1,000) and the DCs (20.2). See also table 2, panel C.

tries would be cut by more than half; and the crude birth rate for the LDCs would be somewhat over 30 per 1,000 (compared with about 20 for the DCs), instead of over 43 per 1,000 as shown now.

5. DISTRIBUTION OF BIRTHS BY PARITY

Parity refers to the birth order in the childbearing sequence for a given mother—first birth, second, third, and so on. It suggests the number of children presumed to be living when the given

TABLE 8

Distribution of Births by Birth Order, Less Developed and Developed Market Economies, Early 1960's

	Number of Countries (1)	Shares of Births in Increasing Order (Parity)							
		1 (2)	2 (3)	3 (4)	4 (5)	5 (6)	6 & 7 (7)	8+ (8)	Total (9)
Less Developed									
1. East Southeast Asia	4	18.4	16.9	14.9	13.0	10.9	14.9	11.0	100
2. Middle East	2	17.2	19.7	16.1	13.9	11.0	14.0	8.1	100
3. Latin America	12	21.6	16.7	14.5	12.0	9.6	13.2	12.4	100
4. Total LDCs, weighted		18.8	17.1	15.0	12.9	10.7	14.6	10.9	100
Developed									
5. Europe	13	36.5	29.4	16.4	8.3	4.2	3.5	1.7	100
6. Overseas offshoots	4	28.9	24.8	18.5−	11.7	6.6	6.0	3.5	100
7. Japan	1	47.5	35.7	11.8	3.0	1.1	0.7	0.2	100
8. Total DCs, weighted		35.4	28.7	16.5−	8.7	4.6	4.0	2.1	100
Contributions to Crude Birth Rates									
9. LDCs		8.2	7.4	6.5	5.6	4.7	6.3	4.7	43.4
10. DCs		7.2	5.8	3.3	1.7	0.9	0.9	0.4	20.2
11. Line 9 minus line 10		1.0	1.6	3.2	3.9	3.8	5.4	4.3	23.2
12. % Distribution of line 11		4	7	14	17	16	23	19	100

Notes:

Lines 1–3 and 5–7: The underlying data are from United Nations, *Demographic Yearbook, 1969* (New York, 1970), table 17, supplemented for one or two countries by the *Demographic Yearbook, 1965* (New York, 1966), table 16.

The data refer primarily to 1963, but another year was taken if data for 1963 were missing or their coverage was incomplete. No adequate data were available for Sub-Saharan Africa.

Percentages were taken to totals excluding the unallocated, except for Mexico where the unallocated were combined in the source with the top parity group (but the effect on column 8 is negligible). For Sweden, the shares of the two top parity groups had to be estimated from the averages for the other twelve countries in the region.

Line 1: Includes Pakistan, West Malaysia, Philippines, and Thailand. The data for India, relating to a limited sample of urban communities, could not be used; therefore, we took an unweighted mean of entries for the four countries.

Line 2: Includes Tunisia and the United Arab Republic.

Line 3: Includes Costa Rica, Dominican Republic, El Salvador, Guatemala, Jamaica, Mexico, Panama, Chile, Colombia, Ecuador, Peru, and Venezuela.

Lines 4 and 8: The weighting was the same as that in tables 1 and 2.

Lines 5–6: The coverage is the same as that in table 1.

Lines 9–10: The percentage shares in lines 4 and 8 were applied to the crude birth rates for the LDCs and DCs (43.4 and 20.2 respectively, see table 2).

Lines 11–12: Calculated similarly to lines 28–29 of table 2.

birth occurs—although these statistics could be estimated directly if data were available on numbers of surviving children cross-classified with the occurrence of the next birth. Parity data also shed some light on the age of parents, since, obviously, high parities, i.e. high orders of birth, are connected with advanced ages of mother and, particularly, of father. The two connections—between parity and older siblings, and between parity and age of parents—set the lines for the discussion here of the summary data.

In table 8 we show the distribution of births by birth order for the LDCs and the DCs. The coverage for the LDCs omits Sub-Saharan Africa for which the data are not available, and is quite limited for other regions. But for the three subregions shown, the distributions are quite similar: the share of the high parity births (i.e. the fifth and higher order) is 37 per cent for East Southeast Asia, 33 per cent for the Middle East, and 35 per cent for Latin America. There is somewhat greater variation among the developed countries: the share of the same high parities is less than 10 per cent for Europe, only 2 per cent for Japan, and 16 per cent for the overseas countries. But each of these, and their average, about 11 per cent, are distinctly below the shares of high parities for the LDCs. The finding is not surprising since we found in table 1 that complete fertility averaged about 6 children for the LDCs and less than 3 children for the DCs—and thus clearly implied much greater proportions of births of high parities in the LDCs than in the DCs.

Nor is it surprising that the high parity births account for much of the excess of the crude birth rate in the LDCs over that in the DCs. Births of the fifth and higher orders contribute close to six-tenths of the total difference in the crude birth rates between the LDCs and the DCs (line 12). Thus, if the proportions of high parity births to total population were the same for the LDCs as for the DCs the crude birth rates would differ by only four-tenths, i.e. would be somewhat below 30 per 1,000 in the LDCs, instead of the 43.4 per 1,000 for the late 1960's.

But we are more concerned here with the connection between births of high parity and the presumed number of older surviving siblings. For the latter we require data on mortality for the younger ages, which are even scarcer for the LDCs than those on births by parity. But we can approximate the necessary coefficients for Latin America, the only subregion among the LDCs for which the coverage in table 8 is adequate.

Estimates of survival of children to age 5 are available for a number of Latin American countries.[7] For 1955–1959 (the latest quinquennium shown), the number of survivors at age 5 (from an initial cohort of 1,000) varies from a high of 929 for Argentina to a low of 787 for Guatemala. The arithmetic mean number of survivors for 11 countries (excluding Argentina, but comprising Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Panama, Peru, and Venezuela) is 849. But we also need estimates of survivors to ages from 10 to 20. We know from the standard sources that age specific death rates between age 5 and the late teens are extremely low. We have, therefore, assumed a relevant survivor estimate to high parity ages of 800 to 825 for Latin America or a cumulative mortality of 175 to 200 per 1,000. For the DCs we have assumed 925 to 940 survivors, or a cumulative mortality of 60 to 75 per 1,000 (a sizable error in this estimate will have little effect on our comparison).

The comparison of the birth parity grouping for Latin America, with that for all the DCs is given in the following tabulation:

	Contribution to CBR, Low Parities (1–4)			Contribution to CBR High Parities (5+)		
	Total (1)	Survival rate (2)	Adjusted (1 × 2) (3)	Total (4)	Survival rate (5)	Adjusted (4 × 5) (6)
1. Latin America	28.7	0.825	23.68	15.6	0.80	12.48
2. DCs	18.0	0.940	16.92	2.2	0.925	2.04
3. Excess, Latin America over DCs	10.7		6.76	13.4		10.44

Note: The contribution for Latin America was calculated by multiplying the shares of parity groups in total births (line 3, table 8) by the total crude birth rate of 44.3 per 1,000 (for the latter see table 2, line 13).

The data show that by the time the average mother in Latin America gives birth to her fifth child, she must have over three surviving children. Moreover, the contribution even of mothers with birth parity below 5, in terms of surviving children, 23.7 per 1,000, exceeds not only the total surviving birth rate (18.96) but also the total crude birth rate (20.2) for the DCs. Yet the contributions to the crude birth rate in Latin America continued beyond the fourth birth order —with the survivors of these high births exceeding those in the DCs by over 10 points and accounting for about six-tenths of the total difference in the proportion of surviving births (to

---

[7] See O. Andrew Collver, *Birth Rates in Latin America: New Estimates of Historical Trends and Fluctuations.* Research Series no. 7, Institute of Studies, University of California, Berkeley, 1965. The estimates are taken from tables 11, 16, 19, 22, 28, 31, 34, 37, 40, 44, 47, and 50, pp. 66, 81, 89, 99, 116, 121, 127, 135, 144, 154, 160, and 169.

TABLE 9

SHARES IN TOTAL BIRTHS OF HIGH PARITY BIRTHS TO OLDER MOTHERS, SELECTED LDCs AND DCs; AND CONTRIBUTION TO DIFFERENCES IN BIRTH RATES, SELECTED COUNTRIES

A. Shares in Total Births of High Parity Births (5th and over) to Older Mothers (%)

	Age of Mothers				
	30–34 (1)	35–39 (2)	40 and over (3)	30 and over (4)	All ages (5)
Less Developed					
1. Philippines, 1963	10.7	9.0	3.7	23.4	35.4
2. Thailand, 1964	11.0	10.3	5.5	21.8	32.9
3. United Arab Republic, 1966	7.2	9.4	5.7	22.3	25.9
4. Guatemala, 1963	10.3	8.5	3.8	22.6	33.1
5. Colombia, 1964	11.0	9.6	3.9	24.5	30.3
6. Average, lines 1–5	10.0	9.4	4.5	23.9	31.5
Developed					
7. France, 1963	7.0	4.4	1.9	13.3	14.2
8. Germany, Federal Republic, 1964	2.3	2.1	1.1	5.5	6.6
9. USA, 1964	5.7	4.0	1.3	11.0	17.4
10. Japan, 1963	0.7	0.8	0.3	1.8	2.4
11. Average, lines 7–10	3.9	2.8	1.2	7.9	10.15

B. Contribution to Differences in Birth Rates

	Shares of High Parity Births (%)		Contributions to CBR	
	Mothers, aged 30+ (1)	Mothers, aged 35+ (2)	Mothers, aged 30+ (3)	Mothers, aged 35+ (4)
12. LDCs	25.7	15.9	11.2	6.90
13. DCs	8.2	4.2	1.7	0.85 –

Notes

Panel A: The data are from United Nations, *Demographic Yearbook, 1969* (New York, 1970), table 17. We chose the major countries in the regions for which data were available, to secure a rough approximation. Because of the limited coverage of the less developed regions, other than Latin America, even inclusion of all reporting countries could not yield adequate representation.

Panel B, columns 1 and 2: First we derived the ratios of the shares of high parity births for the older mothers to the shares of high parity births for mothers of all ages (i.e. the ratio of column 4 to column 5, in lines 6 and 10 for column 1 or of the sums of columns 2 and 3 to column 5 in lines 6 and 10, for column 2). These worked out to 0.71 and 0.44 for the LDCs and 0.77 and 0.39 for the DCs. We then applied these to the total shares of higher parities in table 7 (i.e. 36.2 per cent for LDCs and 10.7 per cent for the DCs), to secure the entries in lines 12 and 13.

Panel B, columns 3 and 4: The shares in columns 1–2 were multiplied by the total CBR for the LDCs (43.4) and for the DCs (20.2), respectively. The calculation thus parallels that in panel C of table 2, except that here it is limited to a comparison of higher parity births to older mothers, not of all births to all mothers.

about age 20) between Latin America and the DCs. In short, in the LDCs, the high fertility and high birth parities persist *despite* the substantial number of surviving children within the families that continue to grow. The mortality rates may be somewhat higher in the other LDC regions than in Latin America, but the conclusion is likely to stand.

We turn now to the connection between high parities and the advanced age of parents. The relevant data provide cross-classifications of births by parity and age of mother alone, and for only a few countries, particularly among the less developed. Hence we present the data for a few individual countries, and do not attempt to derive comprehensive averages (table 9). However, the general order of magnitudes suggested would probably be confirmed by more abundant data if they were available.

Needless to say, the role of the older mothers in high parity births is substantial. Thus the average for the five selected less developed countries shows that of 31.5 per cent, the share of high parity births in the total, over four-tenths was contributed by mothers 35 years of age or older. Interestingly, in the DCs also, the contribution of mothers that old to the high parity births was also about four-tenths, although the latter accounted for only about 10 per cent of total births. Given the excess in the age of father over mother, discussed in the preceding section, we may assume that mothers 35 years old or more are to be matched with fathers well over 40; and mothers 30 years old or more imply fathers 35 or more.

Panel B of table 9 provides an illustrative calculation of the contribution of high parity births to older parents to the total differential (23.2 points) in the crude birth rates between the LDCs and DCs. The high parity births to mothers aged 35 or more (and implicitly to fathers well over 40) account for over 6 points, or over a quarter of the total difference in the CBRs between the LDCs and the DCs. The high parity births to mothers aged 30 and over (and implicitly to fathers 35 and older) account for 9.5 points, or almost half of the differential in the crude birth rates.

We have emphasized the large contribution of high parities, associated with sizable numbers of surviving siblings and with the advanced age of parents, to the excess of crude birth rates in the LDCs over the DCs. The reason for this is

This One
23RB-FL2-D2DF

TABLE 10

DISTRIBUTION OF HOUSEHOLDS AND POPULATION BY SIZE OF HOUSEHOLD, LDCs AND DCs, EARLY AND LATE 1960's (PERCENTAGES)

	Size of Household Groups					
	1 (1)	2 (2)	3–4 (3)	5–6 (4)	7–8 (5)	9+ (6)
A. Distribution of Households						
1. East Southeast Asia (8)	5.7	8.8	29.7	28.2	17.8	9.8
2. Middle East (9)	6.0	10.8	28.6	29.3	15.7	9.6
3. Sub-Saharan Afr. (8)	11.4	48.1		20.1	20.4	
4. Latin America (15)	7.4	10.5	27.1	24.9	16.5	13.6
5. LDCs (ex. line 3)	6.0	9.3	29.1	27.8	17.4	10.4
6. Europe (13)	16.9	26.1	37.9	14.5	4.6	
7. Overseas offshoots (4)	10.9	24.7	37.1	19.8	7.5	
8. Japan (1970)	13.1	15.0	44.0	22.3	5.6	
9. DCs	14.0	23.8	38.6	17.8	5.8	
B. Distribution of Population (Same Countries as in Panel A)						
10. East Southeast Asia	1.1	3.6	20.6	29.7	25.6	19.4
11. Middle East	1.2	4.2	19.7	31.4	23.9	19.6
12. Sub-Saharan Afr.	2.7	31.7		24.2	41.4	
13. Latin America	1.5	4.1	19.0	26.0	23.0	26.4
14. LDCs (ex. line 12)	1.2	3.7	20.3	29.3	25.0	20.5
15. Europe	5.4	16.8	41.9	24.4	11.5	
16. Overseas offshoots	3.1	13.9	36.5	29.7	16.8	
17. Japan	3.6	8.3	43.4	33.1	11.6	
18. DCs	4.2	14.3	40.1	27.8	13.6	

Notes:

The major source is the United Nations, *Methods of Projecting Households and Families*, Manual VIII in the series of manuals on methods of estimating population (New York, 1973), table 3, pp. 12–15, which distinguishes the following size classes of households: 1, 2–4, 5–6, 7 and over. To obtain greater detail, we used data from somewhat fewer countries for each region (except Sub-Saharan Africa) taken from the *Demographic Yearbooks* (particularly those for 1962 and 1963, and 1971). From these we derived allocation ratios for the 2–4 and 7+ groups; and applied them to the total shares for these two size groups.

Lines 1 and 8: Include Cambodia, Ceylon, South Korea, Federation of Malaya, Philippines, Thailand, India (allocated within the wider size groups by ratios for Ceylon), and Pakistan. The usual weighting was employed for this region.

Lines 2 and 9: Include Turkey, Iran, Iraq, Syria, Jordan, Libya, Tunisia, Morocco, and the United Arab Republic.

Lines 3 and 10: Include several smaller countries for better coverage: Lesotho, Dahomey, Gabon, Kenya, Mali, Sierra Leone, Liberia, and Zambia. Cameroon was excluded because of the exceptional showing for the 1-person group.

Lines 4 and 11: Include Costa Rica, Dominican Republic, El Salvador, Honduras, Jamaica, Mexico, Nicaragua, Panama, Brazil, Colombia, Chile, Ecuador, Paraguay, Peru, and Venezuela.

Lines 6–8 and 15–17: Coverage is as complete as in table 1. We took the 1970 data for Japan (rather than those for earlier years) to give greater weight to the recent experience (with the rapid changes in Japan's birth rate and family structure).

that these findings must be recognized in dealing with the persistence of the high birth rates in the LDCs. We must, in analyzing the latter, explain not only the connection between the higher fertility and the earlier marriage and younger parents, i.e. at the low parities, but also the relation of high parities to older parents. Why does a family with a mother whose fecundity is declining, and with a father who approaches or passes beyond the age of forty, continue to have high parity births? Why do such families contribute between a quarter and a half of the total birth rate differential between the LDCs and the DCs?

6. DISTRIBUTION BY SIZE OF HOUSEHOLD

The family, a group related by blood-ties and usually residing together, is the unit in society primarily responsible for rearing children to the age of maturity, when they can leave the parental home and assume the responsibilities of adult life. Given the higher fertility, predominantly intra-marital, in the LDCs, the average family should be larger in these countries than in the DCs, if only because more surviving children are brought up within the family fold.

But the family is a complex concept that does not lend itself easily to statistical observation; in the larger meaning, relevant to pooling of economic assets and income for coverage of consumer expenditures and accumulation, a family should include not only the nuclear unit of parents and their children residing together but also others. The available statistics do not refer to the family but to the household—a group of individuals sharing quarters (including single-person households) "who make common provision for food and other essentials of living. The persons in the group may pool their incomes and have a common budget to a greater or lesser extent; they may be related or unrelated persons, or a combination of both." [8] A household can then be wider than a family, since it may include members not related by blood-ties, or narrower since it may exclude closely related members living elsewhere. Still, it is a fairly useful approximation to what may be called the co-habiting family unit, in that households with members not related by blood-ties (e.g. domestic servants, hired workers for a family business, boarders, and the like) constitute limited proportions of all households. Being largely family households, they are relevant to tracing the effects of differential fertility on the number of children within the unit. More important for our purpose—consideration of the possible effects of numbers of children on the economic position of the closely relevant family unit—the household is the unit most often employed in studies of the distribution of income by size.

Table 10 summarizes the data on distribution of households and population by size of household, with emphasis on comparison between the LDCs and DCs. The difficulties with the definition of a household, particularly in cases of unrelated individuals living communally in lodging houses, dormitories, and the like—in addition to those involved in establishing fully the sharing of quarters by a family household with non-related members—yield statistical divergences from the true situation (illustrations can be found in the source in footnote 8). In table 10 these difficulties appear to affect particularly the averages for Sub-Saharan Africa, which suffers also from inadequate country coverage. For these reasons, we excluded Sub-Saharan Africa from the average for all LDCs—although the broad differences between the LDCs and the DCs would not have been much affected by its inclusion.

The larger size of household, and particularly the larger proportion of households and population in the larger units in the LDCs than in the DCs, is clear. Households of seven persons or more are 28 per cent of all households in the LDCs (line 5) and they account for close to a half of total population (line 14), whereas the corresponding proportions in the DCs are less than 6 and less than 14 per cent respectively (lines 9 and 18). By contrast, one-person households in the LDCs are only 6 per cent of the total and they account for about 1 per cent of total population, while the corresponding proportions for the DCs are 14 and 4 per cent respectively.

The arithmetic mean size of household is clearly greater in the LDCs than in the DCs. This mean is easily calculated by dividing the percentage shares of one-person households in the total of households by the share of one-person households in total population (or, with the necessary adjustment, by relating the proportions of two-person households in households and in population). The resultant averages are 5.0 persons per household in the LDCs and 3.33 persons per household in the DCs. This difference, while substantial, may appear to be too narrow, considering that total fertility in the LDCs is over twice as high as that in the DCs (see table 1). However, the average size of household is a weighted arithmetic mean, in which the younger (and smaller) households have a greater weight in the LDCs than in the DCs (see table 2 for relative weights of women in the successive age groups within the childbearing span). If we use the weights in table 2 for women aged 15 to 49 and assume that the size of household corresponding to these ages, grows in the LDCs from 3 for the 15–19 age group of women by one person for each successive quinquennium reaching 9 persons in the age group 45–49, the weighted average size of household works out to somewhat over 5.5. The addition of single-person households (6 per cent of households, but only 1.2 per cent of population) would reduce the arithmetic mean to 5.3;

---

[8] The quotation is from p. 6 of the United Nations manual on *Methods of Projecting Households and Families*, referred to as the main source for table 10 below. A useful, if summary, discussion of the concepts of family and household is found on pp. 5–12.

and if we reasonably assume that households with women aged 50 years and over are, on the whole, smaller, the average of 5.0 obtained from table 10 is consistent with the assumption that during the childbearing cycle the average woman in the LDCs may have over 7 births (accounting for the top size of 9 persons). A similar calculation for the DCs, using a progression in size of household from 2 persons for women 15–19 years old, to 3 for the 20–24 age bracket, to 4 for the 25–29 age bracket, and to 4.5 for the remaining age brackets through 45–49, would yield a weighted arithmetic mean of 3.8, which with inclusion of one-person households (14 per cent of households and 4.2 per cent of population), would be reduced to 3.4—and be consistent with the 3.33 mean derived from table 10, with allowance for the remaining households with women aged 50 years and over. The consistency then is with the assumption that women in the DCs bear 2.5 children (or somewhat more)—less than half of the number assumed in the calculation for the LDCs.

The interest in the conjectural calculations just presented is less in the consistency between the difference in mean size of households in the LDCs and the DCs and the difference in their fertility, than in the emphasis on the fact that the range in the size of households within each group of countries is a reflection of the stages in the life cycle of a family. A new family begins with two members, grows as children are born and have to be maintained within the family for a prolonged period to maturity; then contracts as the parents and children grow older and the children leave to form a new and separate household. The average size of the household is a somewhat artificial measure that is a weighted combination of units of widely divergent magnitudes. It must therefore be remembered that differences in size of household reflect, in large part, differences in the stage in the life cycle of growth and contraction of the various family units.

Two further observations are relevant to the findings in table 10. First, it can be demonstrated that much of the difference between the 5.0 person average household in the LDCs and the 3.33 person average household in the DCs is due to the different proportions of children in total population. In 1960 in the LDCs (excluding Sub-Saharan Africa) the proportion of children under 15 to total population was 42.8 per cent; of persons under 20 years of age—52.5 per cent.[9] The similar proportions for the DCs (Western and Northern Europe and Italy, North America, Australia and New Zealand and Japan) were 27.8 and 33.3 per cent respectively. If we apply these percentages to the mean size of household we find that of the total discrepancy of 1.67 persons, children under 15 accounted for 1.22 persons (or over three-quarters of the difference) and those under 20 years of age accounted for 1.44 persons (or 86 per cent of the difference). The calculation implies, realistically, that few children under 15 or persons under 20 live outside the family unit.

The second observation involves data relating size of household and income per *person;* and is associated with the finding (still to be tested) that if we group households by size, and then divide household income by number of persons, per person income declines fairly consistently as we move up the scale in size of household.[10] If this negative association, however mitigated by reduction of number of persons to equivalent consuming units, is accepted, the significantly wider range in size of households in the LDCs than in the DCs is of further interest. Thus if we assume that the smaller the household, the higher the per person income, and array population in descending order of per person income, using the data in table 10 for all LDCs and DCs, we can interpolate the shares of the top 20 and lowest 50 per cent of population. We find that the average size of households for these two partition groups are 2.17 and 7.90 in the LDCs, and 1.70 and 5.38 for the DCs—the ratios being 3.64 and 3.15, respectively. Again, if the relation between per person income and size of household is negative, the figures suggest that per person income differentials due to differences in size of household tend to be greater in the LDCs than in the DCs.

---

[9] The data are from the United Nations working paper, *Population Estimates by Regions and Countries, 1950–1960,* ESA/P/WP. 31, May, 1970.

[10] For illustrative data for the United States see my paper, "Income-Related Differences in Natural Increase: Bearing on Growth and Distribution of Income," in Paul A. David and Melvin W. Reder, eds., *Nations and Households in Economic Growth,* Essays in Honor of Moses Abramovitz (New York, 1974), tables 1 and 2, pp. 130 and 133. Evidence for Taiwan and the Philippines indicates that this negative association between size of household and income per person is found also in the LDCs.

This, and related, topics are discussed at greater length in my paper, "Demographic Components in Size-Distributions of Income," prepared for a conference on Income Distribution, Employment, and Economic Development in Southeast Asia, held in Tokyo in late December, 1974, under the auspices of the Japan Economic Research Center (Tokyo) and the Council of Asian Manpower Studies (Manila). The paper is scheduled to be published in the proceedings of that conference in late 1975.

Of course, the relation just suggested may not be that simple; and the function connecting size of household and income per person may not be the same for the LDCs and the DCs. But we make the observation here to point at the line of connection between higher fertility in the LDCs, larger average household, wider range of size of household, and hence possible greater effects on differences in per person income associated with households of differing size. Thus, the higher levels of fertility in the LDCs may affect not only over-all levels and growth rates in per capita product, compared with the DCs, but also the *internal* distribution of income by size *within* the LDCs, compared with the DCs, associated with the wider differentials in size of household in the former.

This last observation is also relevant to much of the writing on size distribution of income in recent years. It is almost entirely based on data on household income, with some information on size of household, but with classifications of households by per household rather than per person (or per consuming unit) income. Needless to say, cross-section differences in distributions of households by size, and changes in these distributions over time, would affect these customary measures; and the latter alone could easily be misleading if we are concerned with income per person (or per consuming unit) rather than with income per household. One should also note that the emphasis on effects of fertility on size of household during the successive phases of the life cycle of the household only strengthens the conviction that adequate analysis of income inequalities within a country must take account of the demographic components that affect the size of household, and determine the life cycle of a household—with its parameters different for the LDCs and the DCs, and its possible changes over time within each.

7. CONCLUDING COMMENTS

In concluding this paper, it may be useful to list the findings bearing on the demographic corollaries of the much higher birth rates (over 43 per 1,000) in the less developed market economies (LDCs), compared with those (about 20 per 1,000) in the developed (DCs). These findings are based largely on international comparisons for the 1960's for the market economies—excluding the Communist countries.

(*a*) The age specific fertility rates for women are, for each age group within the childbearing span, consistently and significantly higher in the LDCs than in the DCs. Women in the LDCs begin bearing children at earlier ages, and continue to bear them through later ages, than women in the DCs. The proportions of younger women within the childbearing span are also somewhat higher in the LDCs than in the DCs—a factor only partly offset by the lower proportion of all women of childbearing ages within the total population of the LDCs. The higher fertility of the very young women (under 20 years of age) and the older women (35 years or more) in the LDCs accounts for almost four-tenths of the total difference in crude birth rates between the two groups of countries.

(*b*) The higher age specific fertility rates of women below age 25 in the LDCs is associated with a significantly higher proportion married in these young age classes—both as compared with the DCs. Indeed, intra-marital fertility rates for women 15–24 are somewhat *lower* for the LDCs than for the DCs. The early marriages of women in some of the major LDC regions (particularly the populous countries in Asia, and in Sub-Saharan Africa) suggest a direct transition of a young woman from the parental household to the household of her husband. In the DCs, on the other hand, young women spend several years on education and work outside the parental household before marriage.

(*c*) The differential in the age of married men between the LDCs and the DCs is far narrower. This is true both at time of marriage and within the married state. The bridegroom or husband is between 5 and 8 or 9 years older than the bride or wife in the LDCs, as compared with 2 to 3 years older in the DCs. The composition of the parental couple (even setting aside some incidence of polygyny in the LDCs), with regard to the disparity in age and experience between husband and wife, is clearly different in the LDCs from that in the DCs—with implications for decisions concerning births and children.

(*d*) Given the extension of childbearing to the more advanced ages of women, and the substantial age excess of husbands over wives in the LDCs, it follows that older fathers account for a larger proportion of births in the LDCs than in the DCs. The estimates suggest that fathers 40 years or older account for almost a quarter of all births in the LDCs, but for only about a tenth in the DCs; and that a third of the total excess of crude birth rates of the LDCs over those of the DCs is due to births associated with older fathers. Thus, much of the difference in birth rates between the two groups of countries is due to higher fertility of younger women and to the excess of births associated with older men in the LDCs, the greater motherhood of younger women, and the greater fatherhood of older men.

(*e*) The higher parity births (fifth or higher order) account for almost four-tenths of all births in the LDCs, for less than one-tenth in the DCs. This difference in the contribution of higher parity births accounts for almost six-tenths of the total difference in crude birth rates between the LDCs and the DCs; and a substantial proportion is due to high parity births to *older* parents (women 35 years or older; men 40 years or older). Thus much of the higher fertility in the LDCs is due to high parity births, incurred despite the presence within the household of well over three children, on the average, and despite the more advanced age of parents, particularly the father.

(*f*) Given the larger number of children within the household in the LDCs—and they can be only within the family household, one of whose main functions is to raise children to maturity and independence—we would expect that in the LDCs the average household would be substantially larger and the proportion of the total population within fairly large households much greater. Indeed, the household in the LDCs averages about 5 persons, compared with 3.3 in the DCs; and the proportion of population in households of 7 or more persons is close to one-half of the total population in the LDCs, and less than a seventh in the DCs. These results, which are consistent with the assumption that fertility rates in the LDCs are over twice as high as those in the DCs, raise intriguing questions concerning the impact of differences in size of households on the measures of inequality in the size distribution of income among households or among persons.

Before we turn to the possible implications of these demographic corollaries of birth rates for the factors that might explain the persistence of high birth rates in the LDCs, one other finding, not explicitly considered so far, ought to be noted. The high fertility rates in the LDCs observed for the 1960's and persisting into the early 1970's, have been maintained despite the fact that in most of the less developed regions, death rates, in general, and infant mortality rates, in particular, have declined substantially over the last three to four decades. Given the assumption that the desired number of children was limited and below total capacity, fewer births should have been needed to achieve a limited total surviving children target. In many of these regions other processes of modernization have spread, either since the 1920's or 1930's, or at least since shortly after World War II. Such modernization should have brought about a modernization of the demographic patterns, particularly lower birth rates and smaller family units.

It would take us too far afield to document this observation in detail. But in view of the relevance of the death rates, and their sharp decline in recent decades in the LDCs, we present a brief summary of the world-wide data easily available, and we supplement it with data for individual countries in Latin America, a less developed region the records for which are relatively good, and the political independence of which goes back a century and a half so that recent decades are not disturbed by major political changes like those that have affected most other less developed countries after World War II (table 11).

We eliminated Mainland China from the aggregates for the LDCs because it is difficult to establish the soundness of the basis of the China estimates for recent years. Three findings can be briefly stated. First, for all LDCs, except China, with the sharp decline in the crude death rates of almost a half (from 30.8 to 16.0), the crude birth rates remained about the same. Infant mortality also declined, perhaps as much as four-tenths. Second, for the ten Latin American countries in panel B, both the cumulative death rates to age 5 and crude death rates for total population declined sharply from 1920–1929 to 1950–1959 (and could be shown to have declined more from 1920–1924 to 1954–1959)—the average decline in the former being about four-tenths and that in the latter somewhat greater proportionately (lines 20 and 21, columns 1–4). Over the same period, crude birth rates barely changed; and when standardized for age structure of women within childbearing ages actually rose (lines 20–21, columns 5–8). Finally panel C shows that

TABLE 11

TRENDS IN BIRTH RATES AND DEATH RATES, LESS DEVELOPED REGIONS AND COUNTRIES

A. Crude Vital Rates (per 1,000), LDCs and DCs, 1936–38 and 1970–75

	DCs (1)	LDCs (2)	China (3)	Other LDCs (4)
1936–1938				
1. Birth rates	24.1	42.5	42.5	42.5
2. Death rates	15.5	31.6	32.5	30.8
3. Infant mortality rates	106	230	na	na
1970–1975				
4. Birth rates	17.2	37.5	26.9	42.0
5. Death rates	9.2	14.3	10.3	16.0
6. Infant mortality rates (1965–1969)	27	140	na	na
Change, 1936–1938 to 1970–1975				
7. Birth rates	−6.9	−5.0	−15.6	−0.5
8. Death rates	−6.3	−17.3	−22.3	−14.8
9. Infant mortality rates (to 1965–1969)	−79	−90	na	na

B. Vital Rates (per 1,000), 10 Countries in Latin America, 1920–1929 (I) and 1950–1959 (II)

	Cumulative death rates to age 5		Crude death rates		Crude birth rates		Standardized birth rates	
	I	II	I	II	I	II	I	II
10. Chile	338.0	145.0	28.85	13.10	43.0	37.3	40.65	37.15
11. Colombia	256.5	192.5	23.05	17.20	44.75	44.55	42.6	44.8
12. Costa Rica	184.5	115.5	23.4	9.9	45.55	45.15	46.0	47.45
13. Ecuador	295.0	197.5	28.55	16.65	48.4	46.45	na	na
14. El Salvador	340.5	197.5	33.45	18.85	46.85	47.9	44.6*	48.35
15. Guatemala	278.5	224.0	33.15	21.7	48.75	49.95	na	na
16. Honduras	210.0	131.5	23.1	13.7	44.2	46.0	43.6*	49.2
17. Mexico	291.0	147.0	27.55	13.05	44.8	45.4	40.45	47.6
18. Panama	172.5	88.0	16.95	9.1	39.5	39.5	37.7*	42.1
19. Venezuela	242.5	121.0	25.3	11.55	42.15	44.25	na	na
Averages (Unweighted Arithmetic Means)								
20. 7 countries (except lines 13, 15, & 19)	256.0	145.3	25.3	13.7	44.1	43.7	42.2	45.2
21. All 10 countries	260.8	156.0	26.4	14.6	44.8	44.6	na	na

C. Crude Vital Rates, Latin America (ex. Temperate Zone), 1950–1955 to 1965–1970

	Death Rates				Birth Rates			
	1950–1955 (1)	1955–1960 (2)	1960–1965 (3)	1965–1970 (4)	1950–1955 (5)	1955–1960 (6)	1960–1965 (7)	1965–1970 (8)
22. Caribbean	15	13	12	11	38	38	37	35
23. Middle America	16	13	11	10	46	45	44	43
24. Tropical South America	15	13	11	10	45	43	40	39
25. Total weighted	15.2	13.1	11.1	10.0	44.4	42.9	40.7	39.5

na—not available

*—the standard birth rate was calculated from the crude for 1920–1929, using ratios of crude to standardized for 1930–1939 or 1925–1929.

Notes

Lines 1–2: Data from United Nations, *World Population Trends, 1920–1947* (New York, December 1949), table 2, p. 10. We took the mid-value of the range shown. DCs comprise North America, Japan, Europe, and Oceania (but exclude Temperate South America, a minor omission here and a minor inclusion under LDCs as compared with line 3 or lines 4–6).

This One
23RB-FL2-D2DF

the decline in the death rates in Latin America continued in the recent two decades, and the crude birth rates too begin to decline, but slowly. In fact, the total absolute drop in birth rates over the last fifteen years was somewhat less than that in death rates (leading to a slight rise in the rate of natural increase). For many of the populous less developed countries in Asia and North Africa (less so for Sub-Saharan Africa) similar rapidly declining death rates and constant or slightly rising birth rates could be found—although for a somewhat shorter period than that covered for Latin America.

There have been other important modernization trends in the LDCs over the recent decades when the high birth rates persisted. We cite the evidence for Latin America to illustrate rather than claim thorough confirmation. The proportion of population in "urban agglomerations"—urban communities larger than small towns of up to 20,000 inhabitants—in the three subregions of Latin America (excluding the Temperate Zone) rose from 10.8 per cent in 1920, to 20.9 per cent in 1950, and to 29.2 per cent in 1960.[11] This trend must have continued through the 1960's. With urban defined differently (and using the national definitions) the percentage of urban to total population for all of Latin America rose from 40.9 in 1950 to 56.7 in 1970.[12] *Per capita* gross domestic product (in constant prices) must also have been rising at a significant rate since the mid-1920's. Approximate estimates indicate an average rise between 1925 and 1950 of about 1.7 per cent per year; between 1950 and 1970 of close to 2.6 per cent per year; and for the full 45 year period from 1925 to 1970, 2.1 per cent per year—suggesting that the level in 1970 was over 2.5 times that in the initial year.[13] One may assume that other aspects of the social structure were also modernized in Latin America (e.g. higher literacy and level of education, improved health, greater levels of consumption). However, the fact that birth rates failed to decline means that modernization was partial, and may have failed to affect some other aspects of the social and economic structure. Finally, one should note that in two other less developed regions the rough indexes of aggregate product per capita rose substantially: from 1950 to 1970 in East and Southeast Asia (excluding Japan) and from 1960 to 1970 in Africa (excluding South Africa).[14]

---

[11] See United Nations, *Growth of the World's Urban and Rural Population, 1920–2000* (New York, 1969), table 47, p. 115, and table 48, p. 116.

[12] See the United Nations background paper prepared for the 1974 World Population Conference, cited for table 11, lines 3 and 6, table 14, p. 30.

[13] The estimates for 1925-1950 are from Alexander Ganz, "Problems and Uses of National Wealth Estimates in Latin America," in Raymond Goldsmith and Christopher Saunders, eds., *Income and Wealth Series No. VIII* (Bowes and Bowes, London, 1969), table III, p. 226. The estimates for 1950–1960 and 1960–1970 are from table 6B of United Nations, *Yearbook of National Accounts Statistics, 1969:* vol. II, *International Tables* (New York, 1970), and *Yearbook of National Accounts Statistics, 1972,* vol. III, *International Tables,* (New York, 1974).

[14] The source for 1950–60 is the United Nations *Yearbook, 1969* and for 1960–70, the *Yearbook, 1972,* both cited in footnote 13. For East and Southeast Asia

---

All other countries are included in the LDCs. China is identified with the region in the source designated "Remaining Far East" (after exclusion of Japan). The population weights used to combine the rates are from table 1, p. 3 of the source.

Lines 3 and 6: From the United Nations Background paper prepared for the 1974 World Population Conference, entitled *Demographic Trends in the World and Its Major Regions, 1950–1970* (New York, April 16, 1974), table 6, p. 15.

Lines 4 and 5: From United Nations, *World Population Prospects, 1970–2000, As Assessed in 1973,* mimeographed, ESA/P/WP.53 (New York, March 1975), table 2.1, pp. 24–26 (birth and death rates) and table 1.1, pp. 12–14 (population totals, used as weights in distinguishing between China and other LDCs). The estimates (under "medium" variant) shown for 1970–1975 are partly projections, but are obviously close to the recent data and are the best estimates for the current quinquennium.

Lines 10 to 21: Calculated from the successive country tables in O. Andrew Collver, *Birth Rates in Latin America*: *New Estimates of Historical Trends and Fluctuations*, no. 7 in Research Series of Institute of International Studies, University of California, Berkeley, 1965. The source shows quinquennial averages, which we converted to initial and terminal decadal averages. The standardization of birth rates in columns 7 and 8 is for the ages of women within the childbearing span (see pp. 42–47 of source for the weighting).

Lines 22 to 25: Calculated from the source cited for lines 3 and 6 above. The death rates are derived by subtracting rates of natural increase (table 7, p. 17) from birth rates (table 5, p. 13). The weighting in line 25 is by population in 1950 for the first quinquennium, average of 1950 and 1960 for the second quinquennium; 1960 population for the third; and the average of 1960 and 1970 for the fourth quinquennium. The population totals are given in table 2, p. 2, of the source.

We come now to the question: why have the much higher birth rates in the LDCs persisted through decades of declining death rates and rising urbanization and per capita income? Only conjectures are possible. The summary findings above, relating to the demographic components of these high fertility levels are only suggestive of a deliberate process. And the extensive literature, bearing largely on fertility differentials and trends in the economically developed countries, is also only suggestive, particularly with respect to the transition theory. The latter outlines a paradigm of a shift from the traditional or pre-industrial to the modern demographic patterns; and thus implicitly indicates the factors underlying the "traditionally" high fertility rates in the current LDCs.[15] But, as has been indicated, one must allow for the different fertility and mortality levels, and the different historical conditions of the current LDCs compared with the vital rates and historical conditions of the presently developed countries in their pre-industrial periods in the eighteenth or nineteenth century. The literature on demographic experience of the LDCs is quite limited, if only because statistical data have become available only recently (and are still deficient) and the accumulation of analytical results has just begun.[16] Nor is it feasible here to comb the limited but still vast literature. The attempt is rather to present a few broad reflections, induced partly by the evidence summarized, partly by the readily available literature on demographic and economic patterns. These, we hope, will be of interest as at least indications of possible directions of further research.

It might help to group the factors that could serve to explain the higher fertility rates in the LDCs under three broad heads: the technology of birth control; the possibly lower costs of larger numbers of children in the LDCs; the possibly higher returns from larger numbers of children in the LDCs. These three groups are not mutually exclusive, and each comprises a wide range of subvariables. But one can secure at least an impression of the relative magnitudes of their contributions to the demographic pattern to be explained, and a notion of the identity of some of the subvariables.

As the quotation in footnote 16 indicates, even in the LDCs fertility is controlled. In all of them some institutions and customs keep fertility below the biological potential. This is a matter of some importance, since it suggests that modernization may destroy or weaken these institutions and customs *before* the new restraining factors associated with modernization become fully operative. But the technology of birth control referred to above is clearly the modern technology, that is far more readily available in the economically

---

the annual growth rate for 1950–1970 in gross domestic product per capita was somewhat over 2 per cent, yielding a cumulative rise of 50 per cent over the two decades; that for Africa for 1960–1970 was only slightly lower. It must be noted, however, that these are aggregates, and make no allowance for divergences among countries or for income inequalities within countries.

[15] For an illuminating summary of the transition theory and the modifications in it in the light of current research see A. J. Coale, "The Demographic Transition Reconsidered," a paper presented at the Liege 1973 International Population Conference of the International Union for Scientific Study of Population, pp. 53–72.

[16] In the 1953 United Nations volume, *The Determinants and Consequences of Population Trends* (New York, 1953), which was a valuable compilation of findings of studies on the relations between population changes and economic and social conditions, the summary of Chapter V noted that statistical data on fertility are lacking, particularly for "most under-developed countries" (p. 96, par. 141) and in referring to factors that account for high fertility ("in the neighborhood of 40 per thousand" p. 97, par. 145) notes "factors such as the nearly universal marriage of women at young ages and the absence of the use of birth control measures." But the summary also notes that even these LDCs have "institutions and customs which reduce fertility substantially below the biological potential."

The revised edition of the volume, United Nations, *The Determinants and Consequences of Population Trends: New Summary of Findings on Interaction of Demographic, Economic and Social Factors, Vol. I* (New York, 1973), contains in Chapter IV a much richer discussion of fertility levels and trends in the high fertility (i.e. LDC) countries; and a wider exploration of the cultural, economic and social factors behind them. But the discussion comments on the difficulties of applying the past experience of the presently developed countries to the current LDCs (see paragraph 134, p. 96); and, in trying to explain why there has been little response of the birth rates in the LDCs to much higher levels of income and lower levels of death rates, still emphasizes the "threshold" hypothesis. The latter assumes that modernization and economic growth must reach some relatively high levels before effects on birth rates may be expected. But as I suggested in another connection, the hypothesis is but another name for the puzzle—rather than a substantive explanation that would specify factors that prevent sizable rises in income and declines in death rates from having an effect (see the comments in my paper, "Economic Aspects of Fertility Trends in the Less-Developed Countries," in S. J. Behrman, Leslie Corsa, Jr., and Ronald Freedman, eds., *Fertility and Family Planning: A World View,* Ann Arbor, 1969, pp. 157–159).

developed countries. In the DCs generally the population is richer and more literate, the transport and communication systems are better, and government has a more permissive or favorable attitude. The implication is that the modern, effective, technology of birth control is ***not*** available to the population of the LDCs, because of high economic costs of delivery, or the indifferent or negative attitude of the government, or both; and that much of the high birth rate is due to *unwanted* births, unwanted by the parents who could have avoided them, given more effective control technology.

There is little question that *some* group in every large population, whether in a developed or less developed country, would have, with better application of better birth control technology, avoided some births that were unwanted. However, "unwanted" is a term subject to many ambiguities in application in quantitative research (unwanted as to timing, or forever, unwanted under what conditions, and the like). Nevertheless, more effective technology and at lower costs would have, in any population, *some* net curbing effect on births—almost by definition of effectiveness and cost. But how significant is such a factor, in explaining the wide differentials in fertility between the LDCs and the DCs?

Several weighty arguments can be adduced to suggest that it is of limited importance. To begin with, age at time of marriage, particularly of women, is clearly an important variable which can be modified, as it has been in the past history of several European and related societies, and thereby affect fertility significantly. This, however, is a change in human and institutional practices, and is little influenced by birth control technology more directly relevant to intra-marital fertility. Furthermore, intra-marital fertility has varied markedly among the current DCs in their pre-industrial phase, when birth control was far less advanced that it is today. These variations find some parallels today among the less developed countries. The two factors just mentioned yielded crude birth rates in the late eighteenth century that ranged from 31 per 1,000 in Norway and Denmark to 38 per 1,000 in Finland, to 55 per 1,000 in the United States.[17]

If the spread of crude birth rates could be so wide with late eighteenth-century birth control technology, one wonders why the current technology within the LDCs has been so inadequate. More important, one may ask why, if more children were seen to lead to economic misery, have the families in the LDCs not manifested a sufficiently strong demand for effective birth control means, a demand that would overcome the indifference of government and the obstacles connected with high costs. After all, other products and aspects of modern technology—ranging from those that reduced death rates so rapidly to popular products like radio sets and Coca Cola—have spread widely and been accepted. If the argument is that established views and ideas, which persist despite changing events, did not encompass the need for modern birth control technology, then the identifiable factor is not the absence of such technology, but the lack of demand for it. Why, then, have the high fertility levels continued to be wanted—presumably by dominant proportions of the population, if not by the small group who really desired fewer children but were inhibited by difficulties in securing effective tools?

In turning now to costs of, and returns from, children, we note first that these costs and returns can be economic, social, or psychological. Then we may also ask what units weigh these costs and returns—giving not only explicit, overt consideration to these minuses and pluses, but also intuitive responses that nevertheless reflect balances. Is it the parental pair, the larger family of which the pair is a member, the larger blood-related collective (tribe, caste, etc.), or even a still larger aggregate that sets the norms to which the parental pair may refer? In the discussion here, we emphasize the economic and related social costs; and given the structure of LDCs, one must bear in mind the possible reference of decisions regarding the number of children to norms established by a much wider, if still blood-related, group than the nuclear, or even the extended, family.

Under the largely rural, family business, conditions in the LDCs, direct and indirect costs of a child are far lower than for the competitive, nuclear family of an economically developed country. In the latter much reliance is placed on the individual earning (or social) power of the father, which would be adversely affected by the economic and other burdens of many children. In a developed economy, substantial earnings and other opportunities for the wife and would-be mother would be foregone, if her time and energy were to be absorbed in childbearing and childrearing. Furthermore, in the developed societies a much greater investment must be made in the rearing of children, so that the direct inputs (as distinct from indirect costs) per child are much higher than in the LDCs. In the latter, only a small investment is needed to rear a child to maturity as an effective economic agent under the conditions of the country and the family.

---

[17] For a convenient summary of these vital rates see Simon Kuznets, *Modern Economic Growth* (Yale University Press, New Haven, 1966), table 2.3, pp. 42–44.

There is little question that the ***absolute*** costs of children, direct or indirect, are far lower in the LDCs than in the DCs. One related point may be added. Because of the closer ties of family in a less developed country to a larger, blood-related aggregate, any unusual costs of the specific family, particularly in connection with children, may be covered, partly at least, by its associates within the tribe, caste, or similar type of group.

Yet one must consider absolute costs in relation to the total income of the family unit involved. Are the direct and indirect costs of a child in the family of a less developed country clearly lower ***relative*** to the total income of the family than the greater costs of a child in a family in a developed country relative to its larger income? If the potential income of the latter is X dollars, and it is reduced to $X\text{-}C$ by the direct and indirect costs of a prospective child, and if the potential income of the former is X/K dollars and it is reduced to $(X/K)-(C/L)$, is L necessarily less than K (K and L being larger than one)? Even if the proportional burden of the monetary magnitude of the costs of a child are the same in the LDCs and DCs, with the generally lower income in the former, the welfare burden would still be greater.

But costs are not independent of returns. They would be independent only if we fixed the latter by assumption. And one may argue that returns are a major factor in any explanation of the persistence of high fertility rates in the LDCs. This judgment reflects the general notion that societies, and groups within them, are responsive to differential cost and return opportunities. Although a long persisting framework of such opportunities clothes the largely rational responses in social norms and ideological garments, once the framework of costs and returns has changed for families or for groups of families, the adjustment should be relatively rapid. If the response, in fact, deviates significantly from the rational content, and if the lag, in fact, is long, one must attempt to establish, in a testable fashion, both the factors that underlie the deviation and the mechanism that generates the lag. Broad references to peculiarities of human nature, or to the existence of a lag, are merely descriptions of the puzzle, rather than explanations.[18]

If then we consider the returns from children, the implication is that the families in the LDCs view children as a source of wealth, the latter defined broadly as economic or social power. Either in weighing costs against returns, or in adherence to social norms still justified in their eyes, the families invest in children because they view them as a source of economic or social gain. This view may be held also by the blood-related collectives larger than the family household or extended family, even reaching into the large politically sovereign aggregates. But in our discussion we shall be concerned primarily with the family.

Three aspects of the investment in children may be distinguished. One is the economic, labor pool aspect, the desire for more children because under the rural or small family business conditions of the LDCs they provide a supply of labor at the disposal of the family that, after some years, provides economic savings and advance far greater than any that could be generated by the same family unit with fewer offspring. A crude calculation, based on reasonably low mortality rates and economical ways of raising the younger generation, might show that the ***net*** contribution of an additional child starting work in his teens and continuing to the early or mid-twenties would be quite substantial—if the child is male, and even if he leaves his family upon marriage.[19] Nor should one overlook the possible contribution of an additional daughter, not only from work within the family, but also in many countries from the bride price or the benefit from the connections with the husband's family.

---

[18] This applies also to the "threshold" hypothesis referred to in footnote 16, and criticized in my earlier paper cited in that footnote.

In that paper, I argued that in explaining the high birth rates in the LDCs a rather limited weight should be assigned to the "purely economic factors" (pp. 160–164). The seeming inconsistency between the position taken then and the discussion here is due largely to the narrow definition of the term "economic factors" in the earlier paper.

[19] See the discussion in Mahmood Mamdani, *The Myth of Population Control: Family, Caste, and Class in an Indian Village* (New York, Monthly Review Press, 1972). This short book is based largely on interviews with members of different castes in a Punjab village that was the focus of an earlier long-term study and prolonged field effort at education in family planning and birth control. One cannot judge the validity of the

The second aspect of investment in children might be designated the genetic pool aspect. It is relevant to those less developed countries in which, because of the inequality within the economic and social structure, investment in greater personal equipment and further education of few children is no assurance of upward social mobility. In these societies mobility is blocked by monopolization of economic and social power by a limited number of families. Under such conditions, advance for the offspring of the lowly is a matter of success based on personal characteristics and endowments, on a kind of genetic lottery that may turn up a dictatorial corporal or general, or a successful athlete (or their female consorts), so prevalent in many LDCs. A rational calculation would encourage a family in such circumstances to have as many children as can survive in passable health to maturity—on the chance that one may be so endowed genetically as to raise himself or herself, and thus also the family, above the low initial level. One should note that both the genetic pool and the labor pool aspects of returns from children apply also to the lower economic groups within the developed countries—particularly if these groups are socially discriminated against.

The third, and widest reaching aspect, of the investment in children is that of security. The latter involves not merely, and not foremost, economic security of parents who, in their old age, have to rely on the help of children, reliance needed in the absence of social provisions for such security in most LDCs.[20] The scope of the security aspect is much broader, encompassing the protection against natural and social calamities, which is *not* provided by government or other organs of society (not blood-related)—and must be supplied by the family, or larger, blood-related collectives. The pressure toward large families has been associated with the weakness and unreliability of governmental structure in many pre-industrial societies, and the need to rely on the family in a weakly organized community that fails to provide adequate protection to the individual member as an individual. Even today, in many LDCs, the need to rely heavily on the family, the tribe, or some blood-tie subgroup different from the national community as a whole, is fairly apparent. So long as the conditions persist, an adequate increase in numbers of those related by protective blood-ties will be a goal, justified even despite possible short-term disadvantages.[21]

To digress from discussion of the family, one should note the decentralization of authority and the intensification of nationalist ties in the world in recent decades; and the prevalence within many national states, particularly LDCs, of regional and ethnic divergences, only exacerbated by uneven pressures of modern economic growth. In these conditions, despite the Malthus argument that the *quality* of population is important, the *quantity* of population has become charged with political significance, and has turned into a tool in international and intra-national contests and potential conflicts. The continuing controversy in Nigeria concerning reliability of the regional population totals in the several censuses is one illustration of the value ascribed to numbers. And the recent stand by Brazil (at the 1974 Bucharest World Population Conference) on its own population-growth aims is another illustration that, in the international power game, numbers are not a sign of weakness but of strength. This is not to deny the desire of Brazil to spread a larger population over its wide

---

results even in terms of the given village, let alone their relevance to a wider field of population experience and motivation among the LDCs. But the book is useful in quoting the reasons adduced by various occupational groups for having more children, particularly sons.

[20] See the analysis in papers by David M. Heer and Dean O. Smith which use simulation techniques to derive the number of births required if, given the mortality levels prevailing in the LDCs, a parental couple wishes to assure a high probability that at least one son will survive to the father's old age. The papers are "Mortality Level, Desired Family Size, and Population Increase," *Demography* **5**, 1 (1968): pp. 104–121, and "Mortality Level, Desired Family Size and Population Increase: Further Variations on a Basic Model," *Demography* **6**, 2 (May, 1969): pp. 141–150.

[21] This argument applies, in particular, in cases of natural calamities and breakdowns of civil authority in internal conflicts. The vulnerability of LDCs to such disasters, combined with the weakness of central authority, is obvious. While natural and social calamities may raise the death rate temporarily, the sustaining long-term effects making for higher birth rates probably more than compensate in the aftermath.

For a suggestive analysis of the key role of the family as a major resource in a recent calamity see Robert W. Kates and others, "The Human Impact of the Managua Earthquake," *Science* **182** (December 7, 1973): pp. 981-990.

open spaces; but it does reflect a point of view, shared by the governments of many other LDCs, large and small, that see advantages in large numbers. These advantages may be envisioned as wider domestic markets and a larger labor force for exploiting unutilized resources, or as a larger protective reserve in a world still beset by international tensions, armed conflicts, and possibly enormous dangers associated with some aspects of modern technology. In any case, the LDCs, in particular, tend to see in larger population a source of strength that they may lack, relative to the DCs, in technology and material capital.

In short, while there may be some validity to the statement that LDCs are poor because they are prolific, it may be said that they are prolific because they are poor. To put it more precisely, they are prolific because under their economic and social conditions large proportions of the population see their economic and social interests in more children as a supply of family labor, as a pool for a genetic lottery, and as a matter of economic and social security in a weakly organized, non-protecting, society. Furthermore, while the private interests of the parental generation may be in conflict with the long-term economic interests of the national community, there is some agreement between the two when we relate families to larger blood-tie groups within the nation and consider the family and the nation in terms of external security interests in a divided and dangerously tense world.

It is hardly necessary to emphasize the speculative character of the comments just made. Yet they are suggested by, and are consistent with, the implications of much of the statistical evidence summarized.[22] The conjectures would be more useful if some attention were given to components of change *within* countries. Thus, it may be that the declining death rates and rising income per capita had different impacts on different groups within the LDCs. It may be that the fertility of some modernizing groups declined, but that of other groups increased, with greater health and nutrition and relaxation of traditional restraints. In that case, the persistence of high aggregate fertility rates would be the result of a balance of conflicting trends within the population, promising a decline as the relative weights of the groups shift. But it was not feasible to pursue these hints here; and in any case, there would be serious data problems in the way.

Nor is it feasible here to discuss the policy implications of the situation suggested by the double statement that LDCs are poor because they are prolific and prolific because they are poor—except to indicate that in many similar situations in the past innovative breakthroughs brought about changes in economic and social institutions and led to the emergence and spread of groups pioneering in new and modern directions.

Finally, one must stress that the above comments constitute judgments on the importance of various groups of factors that might explain the persisting high birth rates in the LDCs—for which I have no quantitative weights derived from tested evidence. They should, therefore, be viewed as tentative and rough, although plausibly inferred from the demographic patterns summarized.

---

[22] Many of the arguments are identical with those used in the *transition* theory to explain "traditional" high birth rates (see the long summary quotation from Notestein in the Coale paper cited in footnote 15).

CRITICISM AS EVALUATION

RENÉ WELLEK

Sterling Professor Emeritus of Comparative Literature, Yale University

(*Read April 26, 1975*)

In many contexts, for many years, I have called for a return to criticism in the original sense of judging, to criticism as evaluation. Both main trends in the history of criticism, revived and redefined in this century, poetics and interpretation, have given up the problem of judgment, of ranking, of the decision about art and non-art. The would-be scientists, the statisticians and the devotees of text grammar and even, in theory, most of the French structuralist critics assembled around the magazine *Poétique* cannot make any value distinctions: they think that making them would violate their ideal of scientific objectivity. Since they are interested in devices and regularities, they plead that these can be observed even in trash or subliterature, *Kitsch* and *colportage*. Northrop Frye, a critic quite apart from this scientific trend of linguistic poetics, argues in the "Polemical Introduction" to his *Anatomy of Criticism* that "the study of literature can never be founded on value judgments." He conceives of literature as a system of fictions in which there is no qualitative difference between a fairy tale and a comedy of Shakespeare. Evaluation is relegated to the history of taste which, like the stock exchange, registers only whimsical fluctuations. What Frye calls "criticism" is a system, an all-embracing timeless scheme in which any and all productions, good and bad, significant and trivial, have to find their place. The new interpreters, particularly the so-called Geneva school, have to come to a similar conclusion as they ask for complete identification with a consciousness behind the work, for an exchange of egos, for an "adhesion so total that it precludes all judgment."

But the task of evaluation is unavoidable, as all students of literature *do* judge, whether they select their text by tradition and reputation or in an individual act of sympathy or enthusiasm. But even after the selection of a text from the millions of books accessible today, constant decisions have to be made as to which of its innumerable traits or relations are to be selected for attention. Choices, explicit and implicit, are everywhere involved; what to exclude and what to ignore, what to single out and what, inevitably, to appreciate and to value. The description of value cannot be divorced from evaluation. A work of literary art cannot be perceived, let alone understood, except as an object of value. Immanuel Kant, in the *Critique of Judgment,* argued long ago that meaning is inseparable from value in the aesthetic transaction. The ideal of a neutral scientific objectivity in literary studies is simply a chimera, a delusion.

Many literary historians recognize that evaluation is inevitable but argue that evaluation is a historical process resulting in the "verdict of the ages," the formulation of a "canon" which can be studied like any other historical phenomenon. Thus Ernst Robert Curtius's immensely erudite *European Literature and the Latin Middle Ages* (1948) has made an impressive beginning in tracing the establishment of the canon of classical writers. No doubt, we can describe, say, the fluctuations of the fame of Dante, who, for a time in the eighteenth century, was dismissed by Horace Walpole, for example, as "extravagant, absurd, disgusting, in short a Methodist parson in Bedlam." Even Shakespeare's fame was not always secure: in spite of the high praise of Ben Jonson and later of Dryden, Thomas Rymer could ridicule *Othello* as a "farce without salt and flavor" and Voltaire could call Shakespeare a "village clown," a "drunken savage," though he admitted that he had found "some pearls in his enormous dunghill."

The view is widespread that we simply have to study the critical situation of bygone ages and have to recognize that there are so many diverse types and styles of literature that no rational choice among them is even possible. Every time had its own poetry and criticism justified in its place. Poetry cannot go wrong nor apparently even criticism, which is only a reflection or justification of contemporary taste. It has, for example, been argued that there are profound "shifts in sensibility" in history and that there is thus a "total discontinuity" in the history of poetry. We have a taste either for Alexander Pope or for William Wordsworth. This view would split the history of literature into a multitude of different periods and areas of sensibility if we push the idea to its logical conclusion and apply it on an international scale and in the whole extent of historical time. We end with complete relativism, with the "whirligig of taste," the tyranny of flux.

Some erudite scholars have been content with this resigned solution. My late colleague at Yale University, Erich Auerbach, the author of *Mimesis: The Representation of Reality in Western Literature,* formulated this historistic creed eloquently in a review of the first two volumes of my *History of Modern Criticism.* He argued that we should not fear extreme relativism. He and others want the critic to see himself historically, in his own limited space and time. The so-called "sociology of knowledge" propounded by Karl Mannheim, in *Ideology and Utopia,* has pushed self-consciousness furthest. But this merely raises the question of all knowing; it leads to universal skepticism, to theoretical paralysis. The case of knowledge and even of historical knowledge is not that desperate. The genesis of a theory does not necessarily invalidate its truth. Men can correct their biases, criticize their presuppositions, rise above their temporal and local limitations. I agree that value, aesthetic or otherwise, is "present only in a certain psychological perspective but it is still present *in* the thing for those endowed with the capacity and training through which alone it can be perceived." Judgment refers to an objective character which is open to inspection. There are, in a work of literature, meanings which I would call obligatory, while other meanings may be only potential or even purely facultative, the additions and associations of the recipient. Most of the disagreements among evaluations are due to the fact that a literary work of art is an assembly of values which are not purely aesthetic. A work belongs to literature, at least in the sense of imaginative literature, of *belles lettres,* because the aesthetic value is dominant. But this does not preclude the presence of other values for which it has been appreciated and praised. They may be moral, political, religious, national, and of course intellectual values. Thus often differences of opinion are not due so much to different responses as simply to the selection of different values in the work.

I have called this view "perspectivism"—possibly a mistaken choice as the term is preempted by the different use by Ortega y Gasset—which must not be confused with relativism. I recognize the impossibility of upholding a rigid absolutism in view of the historical changes of taste and styles, but I also reject relativism which has been considered the necessary consequence of these changes. "Perspectivism" is suggested by the analogy of our seeing, say, a house, very differently from different angles while we still admit that there is a house out there of definite dimensions, layout, material, colors, and so on, which can be ascertained accurately and objectively.

Often differences of opinion are due to shifts in the vocabulary of description and evaluation. Thus when in older periods critics did not call certain works of art beautiful or refused to think of the Alps as beautiful they assumed a narrow concept of the "beautiful" as the pleasant and agreeable. In the nineteenth century the term beauty took over functions reserved before for the "sublime," a word which seems to have almost disappeared from our critical vocabulary.

One should also realize that there is a recognition of value which may not agree with one's feelings of relevance to oneself. I might admire a work of art, value it even very highly, but feel that it does not say anything to me personally, in my immediate situation or mood.

As Roman Ingarden, the Polish phenomenologist, has shown convincingly, a literary work of art must be conceived as a schematic construct which has places of indeterminancy, "white spots," "gaps" which will be filled out differently by different readers. Ingarden speaks of "concretizations," or more simply of the "life" of a work of art, its accretions of meaning in the course of history. But this does not preclude the objective character of this construct and the conviction that ideally and potentially interpretations can be correct. If all interpretations or readings were equal we could not differentiate among them. But it is surely the experience of every teacher that he can and must reject wrong interpretations and that he even can, in concrete cases, refute a wrong interpretation by an appeal to the text or an appeal to the totality of a work while the perverse interpreter may have fastened on some detail or distorted the meaning of a phrase. The concept of adequancy of interpretation leads clearly to the concept of correctness of judgment. Evaluation grows out of understanding; correct evaluation out of correct understanding. I have argued this so many times that I am ashamed of repeating myself. Logic, ethics, and, I believe, even aesthetics cry out against complete relativism. It would lead to a dehumanization of the arts and a paralysis of criticism.

One can classify the main critics of the twentieth century according to the criteria they use. Some impose extra-aesthetic standards: moral, political, national, religious, while others use aesthetic standards drawn from the different periods of literary history. Thus we can speak of revivals of classicism, romanticism, and realism. Then there are, of course, the many critics who defend modernist trends, whether futurism, expressionism, surrealism, or whatever name they bear, as the only right kind of art.

Today we are confronted not only with critics who reject the past in order to create and justify the future or rather their own brand of poetry but we have to face a new nihilism, picking up motifs from Marinetti's futurism and Dada. Vociferously the death of literature is being declared as imminent both here and in France. Thus Norman Mailer tells us that "we have passed the point in civilization where we can ever look at anything as an art work" and Jacques Ehrmann proclaimed that "literature, a dumping ground of fine feelings, a museum of *belles lettres* has had its day." Logically silence is now being recommended as an ultimate solution of all critical problems: by George Steiner, as when he asks "Is the poet's verse not an insult to the naked cry?" and by Ihab Hassan when he denounces, with a quotation from D. H. Lawrence, the green dragon, the evil-smelling *Logos* and rhapsodizes on Pop and Op art, John Cage's music of silence, Rauschenberg's empty canvases in order to advocate a new critical language which would somehow expand man's consciousness of the ineffable and the inexpressible. It is all very modish, vague, and elusive, almost "psychedelic"; and finally almost comically paradoxical as all these apocalyptic prophets of doom and the death of literature continue writing and publishing.

What cannot be dismissed in all of these extravagances is the general revolt against aesthetics which makes anything like agreement on criteria or even on the nature of art impossible. The very existence of the aesthetic response or experience has been denied in recent decades. The theory of empathy which reduced aesthetic feeling to the physical action of inner mimicry; John Dewey's *Art as Experience* (1934) which denies all distinction between aesthetic and other experiences, assimilating aesthetic experience to a sense of heightened vitality; I. A. Richards's writings on literary criticism, which abolish all distinctions between aesthetic and other emotions, are just a few examples of this trend.

But the existence or rather experience of the aesthetic state seems to me undeniable. It is immediately evident and it can be and has been described phenomenologically as "the constitution of a structured self-sufficient, qualitative whole." In this description is already implied a universal criterion: "unity" or "organicity," which must not, however, be interpreted narrowly as merely an endorsement of classicist standards. It is not merely coherence, harmony, the congruence of form and content or "style." It must be seen as a unity which allows a supercession and organization of opposites. We may remember the *discordia concors* which Dr. Johnson sees in John Donne, the union of opposites of Coleridge and his sources, and more recently the views of the New Critics exalting the tensions and paradoxes within a work of art, or even Adorno's view that "the idea of harmony is expressed negatively by embodying contradictions, pure and uncompromised, in its innermost structure." One can argue that even the most impersonal "found objects" can be salvaged for art if we assume that the fact of their being singled out gives them some unity, some allegorical or iconographic meaning. They do express a rudimentary feeling. But many of the latest developments of art amount to a complete denial of art. Harold Rosenberg, in his aptly named book, *The De-Definition of Art,* complains, "No one can say with assurance what a work of art is—or, more important, what is not a work of art." We cannot distinguish between a masterpiece and junk. Nothing is left of art but the fiction of the artist.

Still, one could object that a criterion which merely identifies a minimal requirement for what is art is insufficient as a standard of value. We may even wonder whether a higher organization, a tighter cohesion, necessarily constitutes greater artistic value. I believe this is so in almost all cases. The multiple relations we discover in a great work of art, the implications and complexities *are* a measure of value. Criticism, particularly of the last fifty years, has done much in uncovering such relationships even in apparently simple works.

But one should grant that there may be other universal criteria though it seems difficult to arrive at any one on which there is a universal agreement. The frequently invoked criterion of sincerity, or its modern version, authenticity, remains romantic in implication and derivation: it excludes much stylized, conventionalized art. "Intensity," "local quality," the poetic moment do not get much further. The standard of truth to reality—even if understood broadly—seems to exclude most fantastic, symbolic, allegorical, and Utopian art, as well as the purely decorative and playful. However difficult it has proved to isolate the quality of art, the specific "literariness" in literature, we cannot and must not dispense with the problem of artistic value. All relativism breaks down when we are confronted with the difference between very great poetry and pretentious trash, *Kitsch*. The relativistic argument that we enjoy the art of all ages and peoples can be turned against the defenders of critical anarchy. The fact that we can admire neolithic cave paintings, Chinese landscapes, negro masks, Gregorian chant and Béla Bartók, Homer and Joyce, merely demonstrates that there is a common feature in all art which we recognize today more clearly than in earlier ages, more encumbered by the burden of the past, more restricted by inherited prejudices and limiting tastes. A proper historical sense should not lead to relativism at all: it rather should enable us to perceive the fullness and variety of the world of art. There is a common humanity which makes all art, however remote in time and place, accessible to us. We can rise above the limitations of traditional tastes into a realm, if not of absolute, then of universal art, varied in its manifestations but still amenable to description, analysis, interpretation, and finally, inevitably, to evaluation.

I. MINIS HAYS, SECRETARY, LIBRARIAN, AND BENEFACTOR OF THE AMERICAN PHILOSOPHICAL SOCIETY

WHITFIELD J. BELL, JR.

Librarian, American Philosophical Society

(Read April 24, 1975)

DR. I. MINIS HAYS, writing his will in 1921, directed that the income of his considerable estate, after the deaths of his daughters, should be paid to the American Philosophical Society, whose secretary and librarian he had been since 1897. He gave specific directions how it should be spent —half for the purchase and binding of books for the library, the remainder for such purposes of promoting useful knowledge as the Society might approve, except that a small amount might be used to defray the costs of luncheons and a dinner for the Council and members attending the annual General Meeting, "provided that such entertainment be given in a spirit of modest hospitality." In addition, Hays bequeathed such of his furniture, clocks, silver, china, crystal, and paintings as might be appropriate for a room in "any fire proof hall" the Society might erect thereafter. These bequests, which reflect many of his deepest concerns for the Society, were made, Hays explained, in the conviction

> that after laying a foundation of Higher Education in College it is important to continue the stimulus of study and investigation during the following years which are most productive in the span of life and offer prospect of the highest results in promoting useful knowledge, and that this stimulus can be best exerted through the medium of societies of learned men, the endowment of which with means to carry on such work has been largely neglected while college education has been most bounteously endowed.[1]

Isaac Minis Hays, a native of Philadelphia who rarely traveled far from that city and died there at the age of seventy-eight, was born on July 26, 1847, the son of Isaac Hays, a distinguished physician, ophthalmologist, and for more than fifty years editor of the *American Journal of the Medical Sciences*.[2] At the age of eleven young Hays was sent to the famous Classical Institute of the Rev. Dr. John Wiley Faires in Philadelphia,[3] and a few years later to the University of Pennsylvania, where his fellow-students elected him moderator of the Philomathean Society. Upon graduation in 1866 he entered the Medical School of the University, and received his M.D. degree in 1868. But medical practice held little appeal, nor did research. Hays had few patients, and in his specialty of ophthalmology he appears only to

FIG. 1. I. Minis Hays (1847–1925). Oil portrait by Lazar Raditz. Presented by the Wistar Association to the American Philosophical Society, 1917.

---

[1] Hays, Will, dated Oct. 22, 1921. Copy in Amer. Philos. Soc.

[2] Especially valuable for its characterization and personal recollections is Hampton L. Carson, "Address in Commemoration of I. Minis Hays," *Proc. Amer. Philos. Soc.* **65** (1926): pp. iii–xxxii. See also William J. Taylor, "Memoir of I. Minis Hays, M.D.," College of Physicians of Philadelphia, *Transactions,* ser. 3, **48** (1926): pp. lxxx–lxxxi.

[3] Charles J. Cohen, *Memoir of Rev. John Wiley Faires, A.M., D.D., Founder and Principal of the Classical Institute, Philadelphia* ([Philadelphia], 1926), pp. 362–364.

have edited, with added selections, notes, and illustrations, the American edition of J. Soelberg Wells's *Treatise on the Diseases of the Eye* (1873) and to have prepared, some years subsequently, a statistical survey on "Blindness: Its Frequency, Causes, and Prevention" for William F. Norris and Charles A. Oliver's *System of Diseases of the Eye* (1897). In 1869 Hays joined the staff of the *American Journal* as assistant editor to his father, and thus began the work in which he made the most lasting professional contribution.

Young Dr. Hays rapidly assumed increased responsibilities for the *Journal,* and after his father's death in 1879 he became its editor. He solicited articles and editorials, assigned reviews, and sometimes wrote one himself.[4] He scheduled issues, enforced deadlines on contributors and printers alike, and kept a close scrutiny on costs. He did not, however, hesitate to instruct his correspondents, despite the cost, "to use the wires" to send important stories to Philadelphia quickly.[5] Anticipating the centennial of American independence, Hays commissioned four historical articles that were intended to sum up "what has been done in this country during the century for the advancement of Medicine, Surgery, Obstetrics and Gynecology, and Medical literature."[6] They appeared in four successive quarterly issues of the *Journal* in 1876 and were reprinted at the end of the year in a volume entitled *A Century of American Medicine.*

Subscribers to the *American Journal* received also a monthly periodical called *Medical News and Library,* a sixteen-page magazine filled chiefly with extracts from other journals. In 1881, doubtless at Hays's suggestion, the publishers, to make the magazine a more effective channel of professional intelligence, enlarged it and made it a weekly. Hays was its editor as well as the *Journal*'s. A weekly medical journal like *Medical News,* he wrote in the first issue,

> must be the medium of transmitting the earliest intelligence of medical discoveries and progress; it must, in its editorial columns, represent the living thought of the day, and, while holding positive views, fully, fairly and forcibly discuss all current topics which interest the profession scientifically, socially, or politically; it must present a faithful record of the progress of medical science in all countries; it must give prompt and reliable information concerning all matters, wherever they may be, which are of general medical interest; it must, in fine, fulfil the role of a professional newspaper.[7]

To promote these objectives Hays appointed special correspondents in other cities to report the proceedings of local societies, note important publications, and forward copies of original lectures.[8] One of the most prolific of these correspondents was John Shaw Billings of the Surgeon-General's Library. Another was Professor William Osler of Montreal, and it was at a meeting of the editorial staff of the *Medical News* that the first steps were taken that led to the election of the McGill professor to the chair of medicine at the University of Pennsylvania.[9] Hays himself wrote, among other pieces, editorials on drainage at the White House, compulsory vaccination, the regulation of public slaughter houses, fire escapes in hospitals, the proper care of doctors' horses, and sports for women. "In time," he declared, "we hope that the American woman will not only have legs, but know how to use them; having a back, will be unconscious of it; and in time of emergency be able to swim or to row, to shoot or to climb almost as well as her brother." In the columns of *Medical News* Hays warmly endorsed Billings's proposal for an index-catalogue of the Surgeon-General's Library, printing recommendatory notices and offering to lobby with a congressman patient, if that "would be of any service in aiding you to get an appropriation." [10]

---

[4] *American Journal of the Medical Sciences* **78** (1879): p. 233; **79** (1880): pp. 251–52; **80** (1880): p. 545, for examples.

Papers, New York Public Library.

[5] Hays to John Shaw Billings, May 18, 1882. Billings

[6] Hays to Billings, June 12, 1875; see also Hays's letters Feb. 20, March 6, 17, May 17, 1876. Billings Papers.

[7] *Medical News* **40** (1882): p. 17.

[8] *Ibid.* **39** (1881): pp. 761–762.

[9] Harvey Cushing, *The Life of Sir William Osler* (one-vol. edit., New York, 1940), pp. 202, 220–221, 238, 259; Hays to James Tyson, Aug. 5, 1884. Osler Papers, Osler Library, McGill University. The Hayses became friends with Osler, and often invited him to their summer home at Point Pleasant, N. J. In 1924, when Hays's daughter Bessie was married in London—somewhat to her father's disapproval—Lady Osler made a point of inviting her and the prospective bridegroom to tea, and urged Hays to come over for the wedding: she would send her car to the boat to bring him to Oxford, or she would look after him in London, and help him with the wedding arrangements. Grace R. Osler to Hays, Sept. 16, Nov. 7, 1924; Hays to Lady Osler, [Sept. 1924], n.d. (drafts). Hays Papers, American Philosophical Society.

[10] *Medical News* **41** (1882): pp. 68–69. The editor retreated from the position the next week, warning

This One
23RB-FL2-D2DF

From his work on these journals Hays acquired considerable reputation as a medical editor. It was understandable, therefore, that his opinion should be sought when the American Medical Association in 1889 considered whether to change the location of its editorial office. Hays's arguments for editing and publishing such a journal in a large medical and cultural center like Philadelphia or New York so impressed at least one member of the Council of the American Medical Association that the latter proposed him as editor of its *Journal.* As it turned out, the Association chose Dr. John M. Hollister of Chicago, and the editorial office remained in that city. It does not appear that Hays took a part, as did his fellow-townsman Dr. Solomon Solis-Cohen, in the lively debate the next year over a proposal to move the headquarters of the Association to Washington.[11]

Meanwhile, Dr. Hays had been elected a Fellow of the College of Physicians of Philadelphia in 1872, and in the following year he was added to the Library Committee of the College. The other members at that time were Washington L. Atlee, John Ashhurst, Jr., Robert Bridges, and Alfred Stillé. Hays threw himself into the committee's work with characteristic energy, and within a year or two became its leading member. At one meeting he reports that the records of the Centennial Medical Committee and of the International Medical Congress, of which he was secretary-general, will be deposited in the College's archives; at another he makes a large gift of books; at a third he urges the College to express support for the publication of a subject catalogue of the Surgeon-General's Library (as he had done in the pages of the *American Journal*).[12] and is appointed to draft its memorial to Congress.[13] Hays was especially concerned that the College library be properly catalogued, and he sought answers to the practical questions his colleagues asked, personally visiting the Library Company of Philadlphia and the Boston Medical Library to learn how much cataloguing cost per card, what size card was most practical, whether Cutter's was the best system to follow. He himself collated the published medical theses of the University of Pennsylvania and made a list of missing titles. He designed charge slips and had them printed. At his urging the Committee drafted rules for the use of the library and directed that henceforth it be open daily except Sundays. Soon the binding of pamphlets and of the College's archives and manuscript collections was begun. In 1880 the College hired a paid assistant for the library—apparently its first professional employee. In 1882 Hays was chosen treasurer of the Library Committee, and in 1885, when Dr. S. Weir Mitchell declined the nomination, chairman.[14]

As the years passed the collection grew steadily, by purchase, by the gifts or deposit of libraries like those of Samuel D. Gross and of the Obstetrical Society, and by exchange with other medical societies. Hays and the Library Committee repeatedly advertised the library to the Fellows of the College; while the president, S. Weir Mitchell, called on them to support it, and himself set an example by making generous gifts of books, manuscripts, and paintings. Inevitably, additional shelving had to be provided; then floors had to be strengthened; finally, alarmed for the safety of their increasingly valuable collection, the Committee installed fire extinguishers and bought insurance. Foresighted Fellows realized that enlarged quarters would one day be required for the College and its library. Looking toward that day, in 1883 Hays obtained appointment of a sub-committee "to elaborate a plan for increasing the usefulness of the Library."[15]

As the library became more important in the College, and the librarian more experienced in his post, the role of the Library Committee in daily administration diminished. This was not at all to Hays's liking. On August 2, 1893, noting "a recent tendency to exercise of power in connection with the management of the Library which

---

against over-exertion by women. *Ibid.*, pp. 97-98. See also, *ibid.*, **40** (1882): pp. 19, 20, 49-50, 51, 76, *et passim;* **41** (1882): pp. 40-41; Hays to Billings, Jan. 6, 1876. Billings Papers.

[11] Morris Fishbein, *A History of the American Medical Association, 1847 to 1947* (Philadelphia, 1947), pp. 135-136, 137, 138, 145-149; William W. Keen to Joseph M. Toner, May 23, 1889; Hays to Edward O. Shakespeare, [June 1889]; Shakespeare to Toner, June 21, 1889. Toner Papers, Library of Congress.

[12] Hays offered to have the International Medical Congress, which was to meet in Philadelphia in September, pass a resolution endorsing the plan. Hays to Billings, Aug. 8, 1876. Billings Papers.

[13] College of Physicians, Minutes, Dec. 4, 1878; Library Committee, Minutes, Oct. 30, Nov. 27, 1875, Nov. 29, Dec. 27, 1878, Dec. 27, 1882. College of Physicians of Philadelphia; Hays to Billings, Dec. 24, 1878. Billings Papers.

[14] Library Committee, Minutes, Feb. 2, 1885.

[15] *Ibid.*, May 2, 30, June 15, 1879, Jan. 7, March 1, 1880, Feb. 26, 1883.

was without authority and in violation of the rules of the Committee," he called his committee together in a special meeting. Strict regulations were now drafted for the purchase of books, binding, the distribution of catalogues, and the conduct of staff members. But these rules, which governed the librarian, also limited the customary role of the Library Committee and its chairman. Hays disapproved the restriction of the Committe's authority. He declined to serve any longer. The College, accepting his resignation with an expression of "its warm appreciation of his long, faithful & zealous services," also declared that it "fully recognizes that to his labours and intelligent persevering care is due much of the admirable state of the great library that now belongs to the College." [16]

In 1876, when he was still to establish himself in the profession, Hays had a part in arranging for the International Medical Congress that was held in Philadelphia in connection with the Centennial Exposition. The local medical societies in October, 1875, announced that such a congress, under the presidency of the venerable Dr. Samuel D. Gross, would be held the next year. As preparations went forward during the winter, some of the most outstanding practitioners in the city were co-opted by the central committee to aid it. The preliminary program was completed in March; to entertain the visitors a round of luncheons, dinners, and evening receptions was scheduled. Hays was chairman of a committee of seven on invitations, then chairman of the committee on credentials; and at the time the Congress opened he bore the title of secretary-general. One can fairly assume from this, and from what is known of Hays' character and subsequent work, that many of the details of organization fell to him, and that he managed all with efficiency and despatch. Over 400 physicians and surgeons attended the Congress, which was held on September 4–6, 1876. Most of the states were represented, including Texas and California; there were a good many Canadians; and Joseph Lister led the English and Scottish physicians and surgeons. One or more men came from Argentina, Belgium, Cuba, Denmark, Helsingfors, Germany, Japan, Sweden and St. Petersburg; two came from Australia.[17]

All these experiences, as it fell out, in general and in detail, were preparation for Hays's work at the American Philosophical Society.

Dr. Hays was proposed for membership in the Society by Drs. Samuel W. Gross, W. S. W. Ruschenberger, and Persifor Frazer—two physicians and a geologist—and was elected on February 16, 1886.[18] But his career in the Society may be said to have opened only in 1897, when he was elected one of the secretaries and appointed acting librarian in place of the ailing Dr. George H. Horn. The time was favorable, for the Society seems to havt started to stir from long decades of lethargy. Hays approved and supported the new spirit, and quickly became one of those guiding it. It was not his disposition, wrote a lifelong acquaintance, "to sit in an easy chair in a sunny corner and browse upon the dusty volumes that chance threw in his way." [19] On the contrary, within a few weeks of receiving his appointments, Hays presented to the Committee on Library and to other committees and the officers of the Society suggestions and measures aimed at reformation that were to occupy them all for a quarter of a century. In many of these changes and improvements lay the foundations of much of the Society's character and achievement to this day.

As the Society's librarian, secretary, and editor for a quarter of a century, Dr. Hays was in effect its first executive officer. During those twenty-five years he is said to have written 48,000 letters on Society business in his own hand, and he personally edited and supervised the printing of twenty-seven volumes of *Proceedings* and *Transactions*.[20] He attended at the Hall almost every day, impressing everything he touched with his passion for order, his clearheaded analysis, his driving physical energy. He was secretary of almost every committee and, because he was "very positive in holding to his own opinion and insistent in carrying through his own plans," [21] he soon dominated and directed, as well as executed, all the Society's work. One who knew him called him a driver. Rarely speaking in public, he sat quietly at the chairman's side, guiding proceedings with a glance or whispered advice or warning. Fond of the old ways, taking an almost palpable pride in the Society's history, he delighted to show visitors its ancient treasures. He made a ritual of admission to membership and opposed every effort to increase the numbers.[22] Most of the members of the Society appreciated his services and deferred to his leadership—but not all. He could be, one eulogist admitted, "irritatingly stubborn" [23]—he sometimes clashed with members as strong-willed as himself. When he overbore them, as usually he did, wounds were left that did not always heal. There were members who refused to attend a meeting as long as Dr. Hays was alive.

---

[16] *Ibid.*, Aug. 2, Dec. 6, 1893, Jan. 3, 1894. Hays was appointed a member of the College's Committee on Pharmacopoeia in 1877 and was a delegate to the National Convention for Revising the Pharmacopoeia in 1880. He was a member of the Committee on Publications, 1882–1884, and was elected a councillor in 1885. After his resignation from the Library Committee, Hays seems to have taken little interest in College affairs. He did not contribute toward the construction of the College's new hall on Twenty-second Street, though he did attend the dedication dinner (possibly as representative of the American Philosophical Society).

[17] John Ashhurst, Jr., ed., *Transactions of the International Medical Congress of Philadelphia* (Philadelphia, 1877), pp. xvi–xvii; International Medical Congress, Manuscript Records, *passim.* College of Physicians of Philadelphia.

[18] Hays to Henry Phillips, Jr., Feb. 20, 1886. Letters acknowledging Election, 2: p. 272. Archives, American Philosophical Society.

[19] Carson, "Obituary Notice," *loc. cit.*, p. xiv.

[20] *Ibid.*, pp. xxi–xxii.

Hays was invited at once to sit with the Committee on Library; when he became librarian in fact in 1898 after Horn's death, he was made a member of the Committee *ex officio*. He took the lead at once. At the first meeting he attended he informed the Committee "that there were practically no rules for the Government of the Library," told them that the library needed a new catalogue, and recommended that henceforth they meet regularly.[24] Money was quickly found, card catalogue drawers and supplies were purchased, and on April 1, 1897, a trained cataloguer fell to work, provided—for Hays had thought to ask—with the Stafford black and Carter crimson ink, and the Estabrook pen No. 312 she preferred. Other staff members were added in the next few years, until in 1901 it was composed of three young women and a page who received $3 a week for his services. While Miss Cruice was organizing her work, Hays consulted his old friend John Shaw Billings, now director of the New York Public Library, on the best system of cataloguing. The Philosophical Society library was at that time arranged according to the "philosophical" classification devised by its librarian J. Peter Lesley in the 1860's, a logical analysis of human knowledge imitating the solar spectrum, in which, in fact, white, red, orange, yellow, green, blue, indigo, and violet cards, files, markers, and other indicators were used.[25] Lesley's system was a marvel of panoramic learning—and utterly unworkable. Neither Billings nor others whom Hays asked thought the Dewey system satisfactory, but no one had a better suggestion for the Philosophical Society's collections, and after some hesitation Hays adopted it.[26] Thousands of books and periodicals, neglected for years, were badly in need of binding. Hays obtained a special appropriation of $250 for the purpose, and $200 more to rebind Audubon's *Birds of America*, John Eliot's Indian Bible "and other rare books;" while at the same time the long task was begun—it was to require fifteen years—of cataloguing and binding the papers of Benjamin Franklin, which had been first arranged and indexed forty years before. He recalled the Penn and Logan papers from the Historical Society of Pennsylvania, where they had been on deposit for twenty years. Having obtained from the Smithsonian Institution a list of learned societies that published proceedings and transactions, Hays inaugurated scores of new exchanges, which greatly extended the library's holdings. Duplicates were identified and sold, and the money used to buy other books; and books falling outside the library's fields of interest were sometimes given away, as a lot of pamphlets on Unitarian theology that had belonged to an earlier librarian, John Vaughan, was sent to the First Unitarian Church.[27] Hays had a bookplate designed and printed. He extended the hours when the Library was open to readers. At the end of 1898 the committee, which now met monthly, submitted its report, which Hays wrote.

In it appeared a prediction and warning that were to be repeated annually for many years: the library required more space. To reinforce the point with the Council, Hays had secured the appointment of a Special Committee on the Needs of the Library, which, as Hays knew it would, endorsed the Library Committee's finding "that the most urgent need of the library to-day is increased accommodation"; and it recommended that most of the North room in the hall be allocated to that purpose.[28] At the same meeting also the curators asked the Council for the same space to display the Society's cabinet. The Council awarded it to the library.[29] The principal curator, Dr. J. Cheston Morris, was no more accustomed than Hays to being thwarted in his wishes. At least twice again Morris challenged Hays, claiming for himself the custody of documents that Hays had recently unearthed in an old desk—"undoubtedly Curators' stuff." [30] In these circumstances, Henry Pettit drafted a statement that explicitly recognized the Society's resolve to develop the library and, to distinguish between "Curators' stuff" and the librarian's, defined what was and was not a writing. Manuscripts, Pettit wrote, were

---

[21] Taylor, "Memoir of I. Minis Hays, M.D.," *loc. cit.*, p. lxxxi.

[22] Carson, "Obituary Notice," *loc. cit.*, pp. xxvii, xxxi.

[23] *Ibid.*, p. xxi.

[24] Committee on Library, Minutes, Feb. 27, 1897. Archives.

[25] *Catalogue of the American Philosophical Society Library, Part I* (Philadelphia, 1863), pp. 1–16. The eighteenth-century flavor of Lesley's classification is strengthened by the use—in 1863!—of the long *S*.

[26] Billings to Hays, March 8, 12, 1897; Committee on Library, Minutes, April 2, 1898, Dec. 26, 1903. Archives.

[27] Cyrus Adler to Hays, Jan. 22, 1897; Committee on Library, Minutes, Sept. 23, 1899. Archives; *Proc. Amer. Philos. Soc.* 37 (1898); p. 337.

> writings by hand (not printed) . . . either with ink, pigment or other chemicals, or by pencil or brush, or stylus of some kind . . . not only upon papyrus, skins, vellum & paper, but also upon wood, stone, metal, terra-cotta or similar durable materials—and may be either in the form of rolls, slabs, tablets, books, papers, documents, or even fan-shaped (Buddhist); *provided* that the hand writing is the chief element of value in the object. If the hand writing is of secondary importance, the object is *not* a manuscript in the Society's interpretation of the term. . . . Whenever feasible and expedient manuscripts should be kept in a separate compartment in the Library, as a part of it, and under the care of the Librarian.[31]

Small wonder that Horace Howard Furness congratulated Hays in 1899 on his "triumphant course at the Philosophical Society." [32]

Once the work of organizing the library was well under way, hardly a day passed, it seemed, when some exciting discovery was not made. Hays announced them in letters and inquiries to friends and fellow-scholars, and in short papers that he and others read before the Society. Thus Julius F. Sachse, at his prompting, described a scarce German broadside turned up in the collection;[33] while Hays himself edited a journal of the siege of Fort William Henry in 1757 found among the papers of James Burd, and wrote "A Note on William Penn's Commission for the Government of Pennsylvania during his First Visit to England in 1684," which he found "among some unarranged papers in the possession of this society." [34] Most famous of all the library's manuscripts, of course, carefully preserved and proudly displayed to visitors for many years, was Thomas Jefferson's manuscript copy of the Declaration of Independence which he sent to Richard Henry Lee. Hays's studies of this and of the first printings of the Declaration, inspired by his recent discovery of a broadside on vellum, were major contributions in their day and are still of value.[35]

There were in fact so many large collections and so many important single documents that Hays sought advice of a Committee on Historical Manuscripts—of which he was secretary—to consider how best "to render them available for historical Study." [36] In consequence of their recommendation calendars were prepared of the Richard Henry Lee, Nathanael Greene, and General George Weedon papers;[37] while arrangements were made with Dodd, Mead and Company to publish Weedon's *Valley Forge Orderly Book* and a new edition, by Reuben G. Thwaites, of the journals of Lewis and Clark, and with Houghton Mifflin Company to publish two important documents, by Thomas Jefferson and William Dunbar, relating to the purchase and exploration of Louisiana.[38]

---

[28] Joseph G. Rosengarten, Report, Dec. 3, 1898. Committee on Library. Archives.

[29] Curators, Report as to the Cabinet, Feb. 22, 1897. Archives; *Proc. Amer. Philos. Soc.* **36** (1897): p. 175.

[30] *Ibid.* **37** (1898): pp. 81–83, 177–178; Morris to Edward J. Houston, Oct. 20, 1899 [*sic*]. Archives.

[31] Henry Pettit, "Remarks upon the Report of Curators as to the Cabinet," April 2, 1897. Archives.

[32] H. H. Furness to Hays, Jan. 9, 1899. Hays Papers, American Philosophical Society.

[33] George P. Winship to Hays, Jan. 15, 1897; Superintendent of the Coast and Geodetic Survey to Hays, Feb. 21, 1900; Henry Charles Lea to Hays, Nov. 21, 1901. Archives; Julius F. Sachse, "An Old Broadside, with a reference to the Throne of Congress," *Proc. Amer. Philos. Soc.* **37** (1898): pp. 45–51.

[34] *Ibid.*, pp. 143–150; **38** (1899): pp. 4–6.

[35] "A Note on the History of the Jefferson Manuscript Draught of the Declaration of Independence in the Library of the American Philosophical Society," *ibid.* **27** (1898): pp. 88–107; "A Contribution to the Bibliography of the Declaration of Independence," *ibid.* **39** (1900), pp. 69–78.

[36] Committee on Historical Manuscripts, Minutes, Dec. 17, 1897, *et passim*. Archives.

[37] Committee on Historical Manuscripts, "Calendar of the Correspondence Relating to the American Revolution of . . . Weedon, . . . Lee, and . . . Greene," *Proc. Amer. Philos. Soc.* **38** (1900): pp. 154–344, and separately.

Just as he revived the library, so Hays reawakened the Society's scientific meetings. Attendance at the semimonthly meetings was depressingly small; the number rarely reached thirty, sometimes sank to six or seven. In 1896 Hays had been on a committee that proposed that three meetings a year should be specially planned around a single topic of general interest. The response to the first of these—on "Factors of Organic Evolution," with papers by Edward D. Cope, Liberty Hyde Bailey, and Edwin G. Conklin—was encouraging;[39] but the idea was novel and was not continued. In 1899, Hays, who was now a secretary of the Society, proposed that a *conversazione* be held to stimulate attendance,[40] but nothing came of that, either. Then, in 1901, Hays suggested that the Society hold an annual general meeting, lasting several days, to which an effort would be made to bring distant members, where wives would be invited and social events would form an important part of the program. As secretary, Hays was now able, as he was willing, to make the necessary arrangements; and his plan was approved. The first general meeting, held on April 3–5, 1902, proved to be a great success—115 attended; and such meetings, scheduled with reference to the meetings of the National Academy of Sciences, became a fixture of the Society's calendar.[41] Sometimes the general meeting was planned around an anniversary or special theme, like the centennial of Darwin's birth and the semicentennial of the publication of the *Origin of Species* in 1909. In 1910 ordinary meetings were reduced from two to one a month, and in 1936 the monthly meetings were dropped entirely in favor of a second general meeting, which takes place in November. Hays's contemporaries unanimously credited the annual general meeting with a principal role in the revival of interest in the Society. Professor William Berryman Scott, who knew the Society as it was both before and after the institution of the general meeting, in 1922 spoke gratefully of the change.

> The Society was in a moribund, or at least a comatose, condition when he [Hays] began his work; and Dr. Leidy about that time described it to me as an example of "how a Society that pretended to demand some measure of distinction from those whom it elected to membership was doomed to sterility and inactivity by that very fact." Now this has all been changed; and the annual General Meeting of this Society, which was inaugurated on Dr. Hays's suggestion, is universally regarded as of great importance. The late Professor Pickering, when Vice-President of the Society, once remarked from this chair that this annual meeting had become, in his opinion, the most important and most interesting scientific event of the year.[42]

Hays's life, in the words of Dr. William W. Keen, was "an Ellipse with Benjamin Franklin and the American Philosophical Society in the two foci."[43] In the long run Hays's work in the Society focus was probably the more important; but it was for his devotion to Franklin's memory and his contributions to "Franklin scholarship" that Hays was best known outside the Society. Indeed, many persons knew (and still know) the Society best through its collections, publications, and celebration of Benjamin Franklin.

Since 1840, when Charles Pemberton Fox of Philadelphia, at the suggestion of the historian Jared Sparks of Harvard, gave them to the Society, the library had owned the largest collection of Franklin's papers. Yet this collection was for years little known and less used. James Parton seems not to have consulted it for his excellent *Life and Times of Benjamin Franklin* (1864); Professor John Bach McMaster of the University of Pennsylvania did not so much as acknowledge the Society's existence, much less use its collections, in his *Benjamin Franklin as a Man of Letters* (1887). A dozen years later, however, after Hays had become librarian, all this was changed: Paul L. Ford made extensive use of the Society's Franklin papers in *The Many-Sided Franklin* (1899), and dedicated it to the Society.

A few weeks after Hays became acting librarian, Talcott Williams, a member of the Society, a journalist who was also a scholar, suggested that the Franklin papers should be calendared. Williams had used the collection himself and knew, he told Hays, that they "contain a large amount of valuable historical information which is to-day practically inaccessible." He thought the job might be done for $100, perhaps even $50. "Dont you think that it would be worth while to do this?" Hays believed it would, and at once recommended to the Council both that the collection be calendared and that the Society celebrate the forthcoming bicentenary of Franklin's birth in 1906.[44] Though neither proposal was then approved, Hays kept both clearly before him, and in 1903 he presented them once more to the Society. This time his approach was carefully planned. As the last paper in a scientific session at the General Meeting that year Joseph G. Rosengarten, chairman of the Committee on Library, described the content and flavor of Franklin's papers, and expressed the hope "that the preparation and publication of a Calendar showing their contents may be completed at no distant day, certainly by the two hundredth anniversary of the birth of our founder, and thus perpetuate his memory." [45] In the business session that opened a few minutes later, Hays by unanimous consent moved the appointment of a committee "to prepare a plan for the appropriate celebration of the bicentennial of the birth of Franklin. . . ." [46]

---

[38] In this connection the Society voted to pay half the cost of acquiring the manuscripts of William Clark belonging to Mrs. Voorhis, Dodd, Mead paying the other half; but the agreement was not concluded. Committee on Historical Manuscripts, Minutes, Nov. 15, 1903, Jan. 4, 1904. Archives.

[39] *Proc. Amer. Philos. Soc.* **35** (1896): pp. 16, 39.

[40] *Ibid.* **38** (1899): pp. 22–23.

[41] Committee on General Meeting, Minutes, June 1, Sept. 28, 1901. Archives. The committee even appointed a sub-committee on publicity. Hays had no part in selecting the speakers for this or other meetings of the Society. *Proc. Amer. Philos. Soc.* **40** (1901): p. **86**; **41** (1902): pp. 36–40.

[42] *Ibid.* **61** (1922): p. xi.

[43] Quoted in Carson, "Obituary Notice," *loc. cit.* p. xxix.

The planning committee was composed of twenty-six of the Society's most prestigious members: Presidents Eliot, Hadley, Gilman, and Wilson, Professors Alexander Agassiz, Samuel P. Langley, and Simon Newcomb, Captain Alfred Thayer Mahan, Alexander Graham Bell, Dr. S. Weir Mitchell, among others. Hays, of course, was secretary and the committee's animating spirit. The Society's plans as they grew received enthusiastic support everywhere.[47] The United States government issued a commemorative medal (designed by Augustus St. Gaudens). The Pennsylvania legislature appropriated $35,000 (cut by the governor to $20,000) for expenses; while the city of Philadelphia as the anniversary day approached illuminated its public buildings, called on the citizens to decorate their houses, and organized a parade. Senator Henry Cabot Lodge led the congressional delegation to Philadelphia; Ambassador Jusserand represented the president of the French Republic; while delegates from 127 universities and learned societies throughout the world assembled in Franklin's city, many of them brought by special trains and private cars ordered up by a sub-committee on transportation whose members included the presidents of the Pennsylvania and Reading Railroads. In addition to scientific sessions and a morning of addresses on Franklin by Horace Howard Furness, Charles William Eliot, and Joseph H. Choate, there were luncheons, dinners, and two academic convocations. At one the University of St. Andrews, through its Lord Rector Andrew Carnegie, conferred an honorary degree on Agnes Irwin, dean of Radcliffe College and a descendant of Franklin; at the other the University of Pennsylvania awarded honorary degrees to twenty persons, including such distinguished foreign visitors as Sir George H. Darwin, Professors H. A. Lorentz, Albert A. Michelson, Ernest Rutherford, and Hugo de Vries, on the Italian inventor Guglielmo Marconi (*in absentia*), and on King Edward VII. All this required prodigies of organization and control, to say nothing of tactful decisions whether to extend an invitation to the American Electro-Therapeutic Association, the Linnaean Society of Lancaster County, and Franklin and Marshall College. All transpired without incident—even memorial ceremonies at Franklin's grave, where fourteen wreaths were laid and four addresses and two prayers were delivered, under the auspices of the Grand Lodge of Masons of Pennsylvania. Grateful members of the Society presented Hays with a handsome illuminated scroll and an engraved silver loving cup.[48]

> To
> I. Minis Hays
> who first devised the scheme of a National and International Celebration of the Two hundredth Anniversary of the Birth of
> Benjamin Franklin
> This Testimonial
> is presented by his Fellow-Associates of
> The American Philosophical Society

---

[44] Talcott Williams to Hays, Feb. 10, March 5, 1897. Archives; *Proc. Amer. Philos. Soc.* **36** (1897): p. 143, 216.

[45] Joseph G. Rosengarten, "The 'Franklin Papers' in the American Philosophical Society," *ibid.* **42** (1903): pp. 165-170.

[46] *Ibid.*, p. 8; **43** (1904): p. 100.

[47] Committee on the Franklin Bicentennial, Minutes, *passim.* Archives; *Record of the Celebration of the Two Hundredth Anniversary of the Birth of Benjamin Franklin . . .* (Philadelphia, 1906).

[48] The scroll is signed with sixty-eight names, the loving cup with seventy-seven. Both are in the American Philosophical Society.

This One
23RB-FL2-D2DF

in witness of their high appreciation of that wise forethought, those broad views, that ardent zeal, and those unwearied labours which mainly contributed to the success of the recent Celebration.

April 20, 1906
"Your praise shall still find room
even in the eyes of all posterity."

As soon as the guests departed, the Committee on the Franklin Bicentennial directed Hays to prepare a memorial volume and also "to secure the services of a corps of assistants to complete the Calendar of the Franklin Papers." The record of the celebration was published within the year. The calendar, in five stout, well-printed volumes, was issued in 1908, both as a supplement to the record and as a separate publication.[49] Containing abstracts of all letters, documents, and other papers in the Society's Franklin collection and in that of the University of Pennsylvania as well, it was both an index to more than half of Franklin's surviving manuscripts and an indispensable source for scholars, who learned they could often rely on it without having to consult the original texts. Though not officially a part of the Society's Franklin program, *The Writings of Benjamin Franklin* (1905–07), edited by Albert Henry Smyth, professor of English in Philadelphia's Central High School and a member of the Society, was undertaken at Hays's suggestion, as Smyth acknowledged, and received his encouraging support throughout.[50]

The members' awakened interest in the Society and its work soon produced calls for larger quarters. So well attended were the general meetings that the hall could scarcely hold them. Furthermore the library was bursting its limits, so that in 1912 books had to be put in storage in the vault of a neighboring bank—the first of a number of transfers.[51] In addition to being small and cramped, the building was plain and shabby. Not for the first time in the Society's history, some members began to dream of spacious quarters in a more elegant part of town. To such sentiments and arguments within the Society's membership were added pressures from outside. The official attitude of the City of Philadelphia seemed to be that Philosophical Hall was an intrusion in the sacred precincts of Independence Square. Charges of "desecration" were echoed by patriotic societies, and even by the Historical Society of Pennsylvania.[52] Hays vigorously supported the idea of removal, proposing that a new, more commodious hall be erected which would be a memorial to Franklin. A bill to this effect failed in the State Assembly in 1908, but the city a few years later showed a willingness to cooperate. At that time the Parkway was taking shape under the forceful and imaginative leadership of Eli Kirk Price. Urged on by Hays and others, the Society voted to leave its hall on Independence Square and build a new one at 16th and Cherry Streets. An ordinance was enacted authorizing the city to acquire land at that location and exchange it for Philosophical Hall. Though the mayor supported the idea, the city was slow to obtain title to the Parkway lots. Meanwhile, anticipating a successful outcome of the city's action, the Philosophical Society took some hesitant steps toward mounting a campaign for funds to build the new hall. In all the inevitable meetings, discussions, conferences, and draftings of memoranda, circulars, and appeals Hays played a large part. War activities, however, diverted everyone's attention for several years. Then in 1922 the city determined to use the 16th and Cherry Street tract for a park. This was not the end of the Parkway scheme, however. In 1925 the Society made fresh plans for a move there, and an architect was actually engaged.[53] These conditions, prevailing when Dr. Hays wrote his will, explain some of its provisions.

Dr. Hays was elected a member of the Wistar Association in 1887 and was chosen to its executive committee in 1902, becoming chairman of the committee in 1910. As dean of the Association after 1915 he particularly relished presiding at its monthly collations, especially those held in his own house. As proud of this century-old institution as he was of the parent Society, Hays saw to it that the 100th anniversary of the death of Caspar Wistar in 1918 was observed with special programs. On that occasion he read a well-rounded account (never published) of Wistar as a scientist and philosopher; and Hampton L. Carson read a centennial history of the Association, for which Hays provided many data. "Without your help and the generosity with which you placed all your matter at my disposal, it would have been impossible for me to have delivered the address." [54] The members of the Wistar Association, to mark the first twenty years of their fellow-member's service as librarian and secretary, presented the Society in 1917 with a portrait of Hays painted by Lazar Raditz.[55]

---

[49] Committee on the Franklin Bicentennial, Minutes, May 10, 25, 1906. Archives.

[50] Albert H. Smyth, ed., *The Writings of Benjamin Franklin* (10 v., New York, 1905–1907) 1: p. xiii.

[51] Committee on Library, Minutes, Nov. 27, 1911. Archives.

[52] Joseph G. Rosengarten to Hays, Nov. 3, 1899; miscellaneous undated newspaper clippings, [1891, 1899], Archives. The Historical Society's resolution, November, 1899, recorded "its high appreciation of the intelligent and zealous efforts" of the mayor and City Councils to restore Independence Square "by the acquisition by the City of all the property on Independence Square not now belonging to it and the removal of all buildings on the Square except the historic buildings facing Chestnut Street. . . ." Copy. Archives.

[53] Special Committee on a Site for a New Hall, Reports, Feb. 10, May 1, 1911, *et passim;* printed notice to members favoring the move to the Parkway, May 10, 1911. Archives.

Hays's decision in the spring of 1922 to resign his offices was received with genuine dismay, for few members had been active in the Society when Hays was not in charge of its affairs.[56] He did not, however, cease altogether from being active —and outspoken—in the Society's councils. He was at once appointed chairman of the Committee on Library. Learning that the Society proposed to convert to a gift articles that had long been on deposit at the Academy of Natural Sciences, he protested the intention and asked to be heard in opposition.[57] He wrote an article on Franklin's Canada pamphlet, *The Interest of Great Britain Considered* (1760), and answered queries from Franklin scholars of a new generation, like George Simpson Eddy,[58] as he had formerly responded to Luther S. Livingston, Sydney George Fisher, and Paul L. Ford. In 1924 he was member of a special committee—and its secretary—to plan an international scientific congress on the scale of the Franklin bicentennial that would commemorate both the Society's two hundredth anniversary and the sesquicentennial of American independence in 1926. But when it became apparent that the city had no plan or organization for something worth while, Hays recommended that the Society celebrate its anniversary in 1927 without reference to the city.[59] He presented a general outline of the plans to a committee of the Society on May 27, 1925. Ten days later, on June 5, during a heat wave of unseasonal intensity, he died of a heart attack at the house at 266 South 21st Street, where he had lived more than forty years.

The changes in the Society that Hays led in making had not altered it. On the contrary, they strengthened it in its traditional and necessary role. The library was expanded and extended, and its holdings made more widely known, more accessible, and more useful to scholars. Under Hays's editorship the Society's publications appeared more speedily and in format more congenial to the expectation of his day. The General Meeting, far from being an innovation, was only planned as the most strikingly successful event in the regular calendar of assemblies. Essentially conservative in the best sense, Hays simply took an old, tired institution and made it an effective instrument for scholarly work in the twentieth century.

The Society's formal resolution spoke of Hays's "keen judgment and strict integrity" and of "his untiring efforts in behalf of the Society." [60] The members of the Committee on Library who had relied on him for twenty-five years, wrote "that we hardly know how to proceed without him." [61]

In the half-century between 1921, when Dr. Hays wrote his will, and 1972, when his estate was settled and distributed, the Society and the world changed in ways he did not anticipate. The Society did not sell its hall and move to the Parkway after all, but remained on Independence Square, where it became a leader in the movement for the preservation of historic old Philadelphia. But, as well as new circumstances permit, the wishes Hays expressed in his will are fulfilled: his portrait hangs in the library, a room there is named in his memory, some of his furniture is preserved for any future occasion when the Council may wish to dine formally in the hall, and the income of his estate, amounting to more than $900,000, supports the work of the institution which had engaged his interest and loyalty for so many years.[62]

---

[54] *Proc. Amer. Philos. Soc.* **57** (1918): p. iv; Carson to Hays, May 6, June 21, 1918, laid in the Society's copy of Hampton L. Carson, *The Centenary of the Wistar Party: An Historical Address* (Philadelphia, 1918). Hays had performed a similar service for Henry Charles Lea twenty years before. Henry Charles Lea, *Sketch of the Wistar Party of Philadelphia* (Philadelphia, 1898), with letters of Lea laid in, in the Society's library. Hays's paper on Wistar is in American Philosophical Society Library.

[55] *Proc. Amer. Philos. Soc.* **56** (1917): p. xi.

[56] William B. Scott, *ibid.* **61** (1922): pp. xi–xii.

[57] Curators' Report for 1922; Hays to Council, Jan. 23, 1923. Archives.

[58] Hays, "On the Authorship of the Anonymous Pamphlet published in London in 1760 entitled 'The Interest of Great Britain Considered with regard to her Colonies and the Acquisition of Canada and Guadaloupe,'" *Proc. Amer. Philos. Soc.* **63** (1924): pp. 1-9; George Simpson Eddy, "Correspondence with American Philosophical Society, 1921–24." Archives.

[59] Committee on the Sesqui-Centennial, Minutes, Nov. 7, 1924, Jan. 22, May 27, 1925. Archives.

[60] *Proc. Amer. Philos. Soc.* **65** (1925): p. xii.

[61] Committee on Library, Report to the Society, 1925. Archives.

---

[62] By the terms of Dr. Hays's will, the Society was authorized to sell at public auction such articles of household furnishings in the bequest as it did not wish to keep. The sale—of silver, Canton and Nankin porcelains, paintings, mahogany furniture, crystal, and a Franklin stove—was held in 1974; it realized $27,340, which was added to the capital fund. Samuel T. Freeman & Co., *Executors' Public Auction . . . June 19, 20, and 21, 1974* (Philadelphia, 1974). A question whether the paintings were originals or copies (as the Society's experts believed) was raised by Nessa Forman, "Were They Worth $12,600 or $150,000?" (Phila.) *Sunday Bulletin*, Nov. 18, 1974.

During the time he was librarian of the Society Dr. Hays appears to have accepted few other obligations. He was for several years a member of the board of managers of the Philadedphia Lying-In Charity for Attending Indigent Women at their own Homes, but resigned in 1909 in protest against the conduct of the treasurer. Dr. G. C. Purves to Hays, Nov. 16, 1909. Hays Papers. He was one of the committee appointed by Mayor Reyburn in 1907 to determine the date of the organization of government in Philadelphia. The committee reported the date was 1683; and Hays was named to the committee to plan the Celebration of the 225th Anniversary of the Founding of Philadelphia in October, 1908. Frederick P. Henry, ed., *Founders' Week Memorial Volume* (Philadelphia, 1909), pp. 2–6; Office of the Mayor to Hays, Feb. 15, 1908. Hays Papers. In 1877 he had been active in reorganizing the Deaf and Dumb Asylum, which had recently been enlarged to hold 320 pupils. "I am particularly desirous of introducing a diet table." Hays to John Shaw Billings, Oct. 29, 1877. Billings Papers.

MEMOIRS OF THE
AMERICAN PHILOSOPHICAL SOCIETY

The Role of Providence in the Social Order. Jacob Viner. **(Jayne Lectures for 1966.)**
Vol. 90. x, 113 pp. 1972. $2.00.

Les Seigneurs de Nesle en Picardie (12e Siècle à 1286). William M. Newman.
Vol. 91. 2 pts., 787 pp. 1972. $25.00.

Gardening Ants, the Attines. Neal A. Weber.
Vol. 92. xx, 146 pp., 192 figs. 1972. $8.00.

A Commentary on the Dresden Codex: A Maya Hieroglyphic Book J. Eric S. Thompson.
Vol. 93. x, 156 pp., 25 pls. (color). 1972. $25.00.

New and Full Moons 1001 B.C. to A.D. 1651. Herman H. Goldstine.
Vol. 94. x, 221 pp. 1973. $5.00.

The Diary of Elihu Hubbard Smith (1771–1798). Edited by James E. Cronin.
Vol. 95. xvi, 481 pp., 1 fig. 1973. $15.00.

Roman Construction in Italy from Nerva through the Antonines. Marion E. Blake and Doris Taylor Bishop.
Vol. 96. xx, 328 pp., 36 pls., 17 plans. 1973. $15.00.

The Life of Arthur Young, 1741–1820. John G. Gazley.
Vol. 97. xviii, 727 pp., 23 figs., 3 maps. 1973. $10.00.

Medical Men at the Siege of Boston, April, 1775–April, 1776. Philip Cash.
Vol. 98. xiv, 185 pp., 11 figs. 1973. $3.00.

Crucial American Elections. Arthur S. Link *et al.*
Vol. 99. x, 77 pp. 1973. $3.00.

John Beckley: Zealous Partisan in a Nation Divided. Edmund Berkeley and Dorothy Smith Berkeley.
Vol. 100. xvi, 312 pp., 6 figs. 1973. $6.00.

Peter Tudebode: Historia de Hierosolymitano Itinere. John Hugh Hill and Laurita L. Hill.
Vol. 101. xii, 137 pp., 2 maps. 1974. $5.00.

Benjamin Franklin's Philadelphia Printing: A Descriptive Bibliography. C. William Miller.
Vol. 102. xc, 583 pp., illus. 1974. $40.00.

The Anschluss Movement in Austria and Germany, 1918–1919, and the Paris Peace Conference. Alfred D. Low.
Vol. 103. xvi, 495 pp., 4 figs., 4 maps. 1974. $8.00.

Studies in Pre-Vesalian Anatomy: Biography, Translations, Documents. L. R. Lind.
Vol. 104. xiv, 344 pp., 54 figs. 1975. $18.00.

A Kind of Power: The Shakespeare-Dickens Analogy. Alfred B. Harbage. **(Jayne Lectures for 1974.)**
Vol. 105. xvi, 78 pp. 1975. $4.00.

A Venetian Family and Its Fortune, 1500–1900: The Donà and the Conservation of Their Wealth. James C. Davis.
Vol. 106. xvi, 189 pp., 18 figs. 1975. $6.50.

Academica: Plato, Philip of Opus, and the Pseudo-Platonic Epinomis. Leonardo Tarán.
Vol. 107. viii, 417 pp. 1975. $20.00.